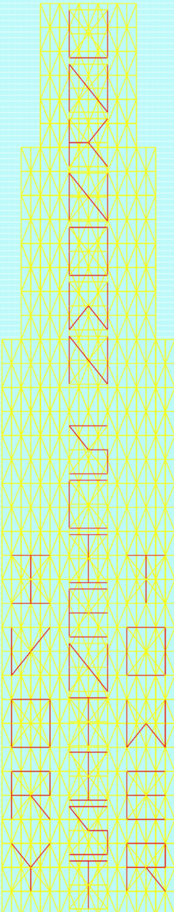
An Unknown Scientist In The Ivory Tower



S T Lakshmikumar

An Unknown Scientist
In The Ivory Tower

An Unknown Scientist
In
The Ivory Tower

S T Lakshmikumar

As I See It

Publication

Published by The Author

stlakshmikumar@gmail.com

Contents

नमो गुरुभ्यः

Acknowledgements

I am deeply indebted to
everyone who helped me learn
through
teaching, discussion and argument.

These essays analyze the status of Indian science, based on my personal experience over the last forty years. I am fully aware that statistical correlations are not a strong basis for confirming causation. Though anecdotes are much worse, I have persisted in using my experience to formulate the analysis. I am personally convinced of the validity of the underlying causes identified here for the malady of Indian science. In the light of this conviction, I do not think the mistakes mentioned here should be simply attributed to individuals. In recounting these anecdotes I have not mentioned the names of individuals involved in these incidents. They are authentic nonetheless and many of my friends have heard me recount these on numerous occasions. The causes I Identified are not likely to be palatable to most. They may be challenged as based on biased anecdotes and not representative of reality. I may be accused of being unpatriotic towards my country or lacking empathy for fellow scientists! I could be blamed for raising these issues now, having availed the benefits of working in the system

all these years, which is admittedly true. I welcome other criticism even if it be emotional and abusive since I realistically expect only benign neglect.

The final essay here is a personal eulogy to Richard Feynman, who along with C V Raman are my idols. They have been significantly influenced my thinking and development all these years. In Raman's case the source of the adulation is the masterly and comprehensive biography by G Venkatraman, *Journey Into Light*. Feynman's personal anecdotes, memoirs and other thoughts have been extensively published posthumously, over the last twenty years. I have had the privilege to read these sources extensively and repeatedly and owe whatever little of value a reader may find here to their inspiration. I am of course responsible for all inaccuracies, errors, mistakes, blunders and muddled thinking.

This book is the consequence of my elephantine memory. These memories have remained fresh all these years primarily because my friends allowed me to repeatedly refresh them during our conversations. I am grateful to Dr. S. Mohan, Dr. S M Shivaprasad, Dr. T D Senguttuvan, Dr. P N Vijay Kumar, Dr. R S Arora, Dr. Ravi Mehrotra, Dr. S C Jain, Dr. S K Jain, Dr. B R Chakraborti, Dr. H K Singh, Shri. S Dwivedi and many others for humoring me all these years and so enabling me to record these. I humbly express my gratitude to Shri. V T V Prasada Rao, my physics teacher in the school for the lessons he taught and training he imparted.

A famous Telugu literary figure Shri. Rallapalli Ananta Krishna Sarma, said of the legendary Telugu poet Vemana, "There are many poets who scolded others for not recognizing talent and offering honors or rewards. Vemana is the only one who scolded because he felt that the society was going in the wrong path". I have tried to emulate this with my pretentious advice. I may be wrong in my conclusions. I am most aware of my own limitations and chose the title after

deliberation. I too wonder if I have the competence to advice. There was an old couplet a senior scientist at NPL, Shri. R Sundaram quoted to me many times and has encouraged me. Translated it says, *the smallest grain of sand and the mighty mountain are both material entities*. Whatever little worth there be in this book, I have not written this book to find excuses or justifications for my lack of success but because I sincerely wish the best both for my country and Indian science. I would be most gratified if at least this is conceded by the readers and the critics.

S T Lakshmikumar

New Delhi
stlakshmikumar@gmail.com

I

An unknown scientist in the ivory tower

Scientists in their ivory tower is a disparaging description of intellectuals pursuing their own interests with complete disregard of practical concerns, both personal and societal. There is an interesting history in the Indian context. The then prime minister, Jawahar Lal Nehru had given a call to the scientists to come out of their ivory towers and help the society. He was partly referring to the fears of atomic wars, a major worry of that era. C V Raman is reported to have countered, saying "the men who matter are those who live in ivory towers. They are the salt of the earth and humanity owes its existence and progress to them".

My view in all matters is practical. Is it so certain that scientists would really help the society if they come out of their ivory towers? Do scientists have miraculous solutions for the myriad problems of the society? Are these problems even solvable by the scientific method? Would the society be receptive to such advice even if the scientist is convinced of his solution? I analyzed the strength of science and its utility comprehensively and

concluded* that the latest science provides vast amount of information but not wise counsel. In the same vein, can every scientist sitting in this so called ivory tower claim to be the salt of the earth, contributing to the existence and progress of humanity? Can a majority even justify their presence in the ivory tower? Does not the presence of such ignoramuses create a stink in the ivory tower?

While delivering a Krishnan Memorial Lecture at the National Physical Laboratory, Rudolf Mössbauer, a Nobel Prize winner declined to enter into an argument of social justification of basic research saying, it is a cultural thing, like an opera house. It is for the society to decide if it wants to spend money not for the scientist. While seeking funds for an extremely expensive particle accelerator, the president of the National Academy of Sciences was asked by a politician in the senate of the United States of America, how the accelerator would contribute to national defense. The tongue in cheek reply was that it would make the country worth defending! The funds were not approved.

In the Indian context, where resources are scarce, decisions to fund science are extremely difficult to take. The demands for tangible technological outputs are perennial as are the counter arguments about the long term benefits of basic research. Indian society is extremely attracted towards higher education. There is a continuous conflict between votaries of merit and of social justice. However, most of the demand for higher education exists because of the attraction of high paying jobs which require higher education and even more importantly, degrees from premier institutions. It is not directly related to Indian science, either as the driving force for developing technology or as a globally competitive intellectual enterprise. The society however, continues to pay homage to advanced science. We claim kinship and take pride in the accomplishments of non-resident Indians. We demand the latest

technology. As a society we look for the scapegoats for the lack of real accomplishments and blame either the shortsighted, profit motivated business class or conspiracies by the racist Westerners.

The unsubstantiated and sometimes idiotic deference to ancient Indian science and preference for non-mainstream and sometimes discredited science is part of this mental makeup. For their part, Indian scientists do their best to insulate the ivory tower from any criticism by the society. The scientific fraternity closes ranks and lack of resources is cited as the eternal reason for all failures. The socialistic mind set of giving primacy to nurture rather than nature is, not surprisingly, as strongly entrenched among Indian scientists as in the society. Intellectual snobbery is another popular defensive mechanism.

After forty years in this ivory tower, a desire to honestly assess the reality has become overwhelming. There are many institutions in India that profess to professionally and quantitatively assess Indian science. Professionals tend to follow the general trend of science for the past three centuries since Newton, namely quantification. However, I have little inclination to defer to the experts. Having had the gumption to analyze the strength of the entire gamut of science, I realized that increased quantification creates an aura of knowledge and is hence employed even when the underlying reality does not justify its use. I no longer feel that expertise or even the lack of credibility are impediments to my effort.

If the professional expert of science studies cares more for peer recognition than reality, an accomplished scientist has neither the time nor the inclination to examine the reality in the ivory tower. Mediocrity, rather than being a handicap, has some advantage in the present effort. Hence the title I have chosen, *An Unknown Scientist In The Ivory Tower*.

My experiences in this ivory tower are collated not chronologically but thematically into three essays. The first, *Bypassing the first lesson*, documents the extensive failure of Indian scientists to rigorously self examine the work they do according to the rules of science. In a way, it lays bare the consequences of the social approach that I outline in the second essay, *Courtesy demands*. This essay details, how in my opinion, what began as courtesy has degenerated into communal hypnosis, sycophancy and a conspiracy of silence. The third essay, *If so poor, why so rich* demonstrates, how easy it is to evaluate the actual reality of Indian science. The three essays together portray a rather dismal picture of Indian science. The fourth essay, *A goddamn philosopher* is an eulogy to Richard Feynman, the man who inspired the audacity to analyze the complexities of Indian science.

Unfortunately there is no quick fix solution that I identify. My own lack of confidence in leadership as a solution to problems has been included in the third essay itself. As with *Swach Bharat*, the cleanliness drive, recently launched with grate fanfare, success will depend on the individual commitment alone. There is no solution as long as most Indians continue to believe that responsibility for discipline is with police and for cleanliness with the scavengers. Admiral Nelson is said to have proclaimed before the battle of Trafalgar, "England expects every man to do his duty". Modifying this, *I expect every Indian to first identify his duty, at each instance, without expecting a set of commandments form someone else and then do it honestly if there is to be real progress.*

---

* How well do we know it? Print on demand publication. pothi.com/pothi/book/s-t-lakshmikumar-how-well-do-we-know-it

II
Bypassing the first lesson

What is the first lesson of science? Even during the elementary classes, a number of scientific facts are presented to the student. In my description, basic factual statements such as "*the earth is round*" or "*things are divided into living and nonliving*" do not form the first lesson of science, even if they are the first scientific statements one learns in school. The first lesson in science was taught to me by my physics teacher, through the first laboratory experiment we did as part of the higher secondary course. The experiment was to determine the area of an irregular object by copying its outline on a graph paper and then counting the number of square millimeters inside the boundary.

The instructions he gave were very specific. Never count the area in units smaller than one square millimeter, the smallest square on the graph paper. The boundary may pass though one of the squares leaving part of the square inside the boundary and part outside. Decide if more than 50% of the square is inside the boundary; if so count it. If by your estimate less than 50% of the

square is inside, do not count it. Never ever combine more than one square and argue that the combination of the little bits inside them sum up to one unit.

The recognition of the importance of these instructions came much later. At that point we simply accepted his statement that one square millimeter was the least count of the instrument, in this case the graph paper. We were quite relaxed about the fact that there was one experiment not to bother about in the practical examination. He was very strict regarding not quoting results to an accuracy better than the least count. If a scale was used to determine the focal length of a lens, woe to anyone who averaged a few observations and wrote the final result to parts of a millimeter. Same for anyone using a physical balance and quoting an average of less than a milligram.

He would point out, 2/3 can have an infinite number of digits in mathematics but one cannot do that for the results of physical measurements. Similarly, even if there is a gap between two marks on a scale and the eyes is able to discern various positions, for example quarters between the two marks, such evaluations have no validity. The marks define the least count or the best accuracy that can be expected with that measuring device and this cannot be enhanced by the user.

Now when I look at those simple instructions regarding counting the squares, I see their importance. Each measurement is a decision. It can have an error equal to the least count. Thus, there is nothing wrong if one individual decides that more than 50% of the square is inside and another that it is not. But each measurement by an instrument is also independent. Hence it is absolutely silly to try and sum up small areas in a few squares. When this is done the graph paper is not the measuring instrument. When quantification is recognized as the approach of science it is most important to

recognize the limits. Thus, I believe in categorizing this as the first lesson of science. Eventually, I learned to evaluate the academic propensity to increased quantification without any concern for justification and utility in various disciplines of science. In the present narrative however, I am looking in a different direction. As I shall try to demonstrate, ignoring this first lesson has a made major contribution to state of the ivory tower in India.

This lesson regarding the sanctity of the least count stayed with me as I progressed into the higher echelons of Indian science. Entering the ivory tower, I was aghast to note how much this first lesson is actually violated. This often led to disagreements and occasionally unpleasantness. One of my early amusing interaction with the cavalier disregard for least count occurred at the National Physical Laboratory shortly after I joined the institution.

The scientists in the acoustics section used a strip chart recorder to record noise levels as they decay and the company had supplied a special scale to determine time constants. This makes it unnecessary for the scientist to actually measure the time on the chart paper and laboriously calculate the time constant. One glance was sufficient to notice that the scale was logarithmic and so the marks on the scale were not uniformly distributed. The scientists were blissfully subdividing the distance between successive marks and sometimes reporting data to an accuracy of about one twentieth the marks on the scale.

To add more hilarity, the trace on the chart paper was not even a simple continuous monotonic curve but a slowly decaying oscillatory one. Fresh from my academic experience, where at least the students could shout at one another on matters of science, I strongly objected. The nice part was that my senior colleague was not offended. He even recollected the incident twenty years later when our families met. But he never really cared for my advice.

The results were being published in professional journals and presented at conferences without any problem. So he felt that the ends justified the means.

Shortly after my joining the laboratory, the then director decided to have a depository of all work being done in the laboratory, published or otherwise, in the form of technical reports. While this lasted, a committee was formed to get these documents internally reviewed. Consequently, there were further opportunities to encounter this cavalier disregard for the first lesson in many other situations. These often ended with more rancor and resentment than in the first case.

One of the first such reports I had the privilege to review resulted in a very memorable comment. A report on the development of a new standard mentioned at the beginning that the measurements were carried on a balance with a least count of 0.1mg. But, all data presented therein were to an accuracy of 0.01mg. True to my first lesson, I objected to the inconsistency. This was strongly resented as coming from a person with *no background in standards activity*. I then met the chairman of the committee, a very senior scientist who remarked "A trained physicist learns to do that." This is something I have been never able to forget. I persisted with my claim that this was not scientific and probably as a consequence had relatively fewer occasions to review such reports.

Thankfully, first reviewing and subsequently the preparation of these technical reports were dispensed with, but not before I came across another memorable statement. The scientist concerned wrote; *we have decided* to report 'x' number of digits though the computer program provided to us by NPL UK, prints many more. I desperately longed to point out that the decision regarding the number of digits to be reported lay with the instrument and not the scientist.

While the formal reviews and the attendant human issues have receded, I have lost count of the number of times my colleague scientists in the standards have tried to convince me of my stupidity. They point to this ambiguous gem of a statement in a standards document IS 4169(1988). "The resolution (r) of the indicator shall be obtained from the ratios between the width of the pointer and the centre-to-centre distance between two adjacent scale graduation marks (scale interval), the recommended ratios are 1:2, 1:5 or 1:10, a spacing of 1.25 mm or greater being required for the estimation of a tenth of the division on the scale".

Whatever be the restricted context in which this was originally drafted, to many of the scientists this was a carte blanche permission to report measurements to one tenth of the obvious least count in analogue instruments. This issue has receded into the background in recent years since most instruments provide digital output but I have rarely seen people worrying about the fluctuations in the last digit with time of observation and what that really tells about the actual resolution.

I have come across many examples in technical and scientific presentations and even refereed publications where the resolutions mentioned in the data are simply incompatible with the claims made by the manufacturers and in some cases with the physical processes employed for the measurement. What should one do when the thickness measurements performed using an ellipsometer, (known to have an accuracy of a fraction of the wavelength of light used) are casually mentioned to an accuracy ten or twenty times more?

The only charitable explanation for this oversight on the part of the authors as well as the reviewers is the irrelevance of the accuracy to the conclusions of the scientific report. Possibly such glaring mistakes are unconsciously overlooked as the attention is

centered on the subject under discussion. But as I will show in my further analysis of the ivory tower, such *minor local issues* do have major global consequences.

Another part of this first lesson in science, one that gave me many amusing moments during my career was also provided by my teacher in the school. In hindsight I am amazed at how perceptive of the value of science my physics teacher in school was. During our practical work we had to perform a number of experiments where we had to determine the slope of a straight line passing through experimental observations. Usually there would be scatter in the data and no line would pass through all the points. He told us that eventually we would learn about the least square procedure but for the present we were to ensure that experimental points which do not lie on the line should be equally distributed on both sides and if possible at equal distances. He explained that we have to take all points into consideration and drawing a line through the maximum number of points is absolutely wrong since you are neglecting those that are not on it. That is a description the students in the higher secondary classes could understand and at the same time carries the essence of the least square procedure.

A most amusing incident occurred in the M. Sc., when we were determining the work function of tungsten by measuring the current in a vacuum tube diode for various filament currents which indirectly changes the filament temperature. I had completed my experiment a couple of weeks earlier. A second student later complained that she was not getting the correct value. So the faculty member asked her to compare with my results. She looked at my graph and complained that I cooked the data since the line was passing through only a few points and that if I had drawn in through the maximum number of points possible, I would also have got a wrong value. She had to be gently told to remember the least square fit procedure which was already discussed in the mathematical

physics course. That was one of the many moments I thanked my teacher from the heart. Of course, in those pre-computer days, performing a numerical least square fit during the limited time available in a practical exam was impossible and the little trick that I was taught in school was quite handy.

That such ignorance about basic quantification persists at advanced levels was painfully brought out when a friend made a mistake which delayed his doctorate degree award very significantly. Having made a measurement very accurately, he confused the accuracy in a measurement with the accuracy of its derivative. Mesmerized by the high accuracy of his measurement, instead of finding the overall curve representing his entire data and determining the slope analytically, he proceeded to determine the slope from individual data points. This error being not detected at early stages, an enormous amount of work had to be repeated. During the discussions about this issue, I demonstrated the simple trick I learnt, of using a mirror, positioning it to form a continuous curve of the line and its image and thus determining the slope, much to the amusement of both my friend and his faculty advisor.

This was also my first experience of the negative feature of Indian science that I believe has been terribly detrimental. The general tendency is to work alone, not discuss openly and even more worryingly, not critically listen to anyone. One does not realize that openness in revealing details of work being done and taking the trouble to seriously criticize others' work are both very essential components of scientific research.

The computer facilities available while working for my Ph. D., even in the best Indian institutions, were primitive by contemporary standards. After all, a typical desk top personal computer of today is about 50 ties more powerful than the main frame computer at IISc, shared by the entire research community. I

remember fondly, the troubles my friends had in doing a non-linear least square fit of their data. It was so critical for the work they were doing and their ability to publish in the best of journals hinged on this. Unfortunately, by their very nature, the non linear fit has no unique solutions. So there were endless discussions on the choice of initial parameters and the confidence in the ultimate results.

The contemporary personal computer has made it all so easy. But at the same time, the scientific community seems to be completely oblivious to the limits of the computation and in particular the use of the software for non-linear fits. Time and again in the recent years, one has seen students routinely offer the results of computation without the least idea of the limits of such calculations. This is a classic example of one having more information than wisdom. I had spent considerable time wondering at this malady in social sciences and it is a sweet irony for me to see this problem creeping into physics.

The above two are examples of a first lesson of science that scientists and in particular physicists know but often violate without quite realizing it. On the other hand, there is a very critical gap in the physics curriculum that contributes to basic mistakes. The physicists do not see the instrument that makes the measurement as a distinct entity between the system under study and the scientist. When one refers to the temperature or pressure or resistance being measured, it is measured by an instrument and there is a time dependent change in the value that is provided by the instrument. Unfortunately human perception is limited to a small range of time scales. Any change less than a second is not perceivable. An average experimenter rarely waits for more than few minutes before recording a reading. It is a basic fact of everyday experience that a clinical thermometer has to be kept in the mouth for more than 30 seconds to record the temperature correctly. But we do not analyze the implications of such practical rules of thumb

in the context of the sophisticated measurements that are performed in the course of scientific research.

An engineer in contrast is often taught the basics of instrumentation and hopefully recognizes that a sensor is itself a system, that it has time dependent characteristics and that its time constants and resonant frequencies are completely independent of the system or material being studied using the sensor. Newton's law of cooling is taught in the higher secondary school physics and could offer a good starting point for such a discussion. But it is taught as a distinct entity and not used for introducing the study of measuring systems.

In the earlier discussion I pointed out certain claims regarding measurements better than the least count. The awareness about the time dependence of measurement offers an additional warning. One has to consider the possibility that the apparently stable measurements one encounters reflect the sluggishness of the system and long time constants. Thus, if the resistance of a sample is being measured as it is cooled or heated, the rate of cooling, the time constant of the temperature measurement and of the resistance measurement are all to be taken into consideration for one to be sure that the interesting results being obtained are not merely an artifact. Even if a sophisticated temperature controller is used, it is important to know the role of the time constants that are being used. Once again, the responsibilities are often left to the computer. I have rarely come across colleagues performing experiments being aware of these subtle issues.

The problem becomes even more tricky when the signals to be determined are time varying or *ac* signals as they are commonly called. Such variations in normal physical parameters are more common than one realizes. As an example, consider the use of an electric water heater. Normally the temperature of the

water increases slowly and the fact that the electricity supply is varying from +230V to -230V, at 50 Hz. is of no consequence. However, it is possible to arrange the thermal system; the amount of water, the size of the heater and how the two are coupled etc. in such a way that the temperature of the water also shows the 50 Hz variation. Such *ac* methods to determine the thermal properties of materials have been extensively investigated. Similarly, the time constants mentioned above can be measured and analyzed to determine thermal properties. While these are established research techniques, many of the researchers are often unaware that this approach must be used to analyze measurements made in other contexts.

The limits on the instrument used to measure such cyclic changes is set by the so called sampling theorem which essentially says that to mathematically reconstruct the signal, it has to be sampled at least twice during one cycle or in the case of line frequency at least 100 times a second. Once again, ideas about sampling theorem, the Weiner Kinchine relations between signals in the frequency and time domains etc, are part of the engineering curriculum but not the physics and science curricula.

Thus, I had the funny example of a colleague offering a wager that he could use two different signal sources to the reference and signal channels of a lock in amplifier and make it work. This incident exposed me to another significant drawback of basic knowledge being offered to Indian students. Unless the operation of the lock in amplifier is analyzed mathematically, it is difficult to see the absurdity of what the colleague was saying. Unfortunately, Indians teachers and students prefer to avoid the mathematical treatment since it is tough on both intellectually. Further, the students do not want to make mistakes and fail to get high marks and the faculty are in a pressure to promote as many as possible which compounds the problem.

This problem of scientists relying on descriptive physics is quite serious and is another facet of the first lesson of science. I remember a senior colleague taking the description of electrons and holes in a semiconductor too seriously and coming up with a new idea. When the idea was openly discussed, itself a rare occasions, it became apparent that under his scheme of things, efficiency was becoming higher than unity. Unfortunately, the basic problem with the idea, considering the quantum mechanical particles as real classical objects could not be easily explained. My suggestion that he should revisit his quantum mechanics course was resented and I was given a dressing down in private by other friends for not being courteous to a senior scientist.

The problems discussed above are very serious but ignored in the Indian context. Today, instruments such as the lock in amplifiers, p-i-d controllers and spectrum analyzers are extensively used not only by physicists but by researchers in chemical and life sciences. The general expectation is that the researchers will not act like trained monkeys and will undertake serious self study of these issues. But studying the new area is seen as an excuse for avoiding work by the seniors who supervise the youngsters and the lack of immediate results is seen as an obstacle to career advancement by the youngsters.

Thus, over the years, I faced repeated examples of the failure of serious well meaning and hardworking scientists not respecting the fundamental constraints of science. Understanding the limitations of the experimental tools and the errors inevitable in any measurement are coupled by not being attentive to the necessity for analytical rigor. It is jocularly said that an engineer thinks that his equations are an approximation to reality; a physicist thinks reality is an approximation to his equations and a mathematician doesn't care. Unfortunately, in the Indian context, most scientists do not seem to care; even as they do not enjoy mathematics! As I

shall discuss next, the desire not to offend creates major problems for Indian science and ignoring the first lesson of science is the first of many. The city of Lucknow is very famous for formality and courtesy. It is exemplified by two gentlemen standing on the railway platform and courteously insisting that the other board the train first, while the train departed without either. The descriptions in the next essay would have been equally amusing but for their being so distressing.

III
Courtesy demands

I was introduced to "*Courtesy demands*" in scientific discussions by a very senior professor. He had just returned after a visit to the soviet union and was giving a lecture about some interesting experiments being done there on hydrostatic extrusion of single crystals. Extrusion changes the outer shape of the object being extruded and is routinely used to make plastic objects. Surprisingly the single crystal remained a single crystal after extrusion into the new shape. While clearly not against any known laws of physics, it was intriguing. One senior scientist made a pompous statement that he would like to know the atomic movements in such a transformation. I was amazed when the professor nodded his head and mumbled something about it being an interesting question. Being quite intimate with him, I challenged him later, pointing out that the transformation was obviously mediated by the phenomenon of slip, something that is taught in the first course on solid state physics. He agreed but then said *courtesy demands* that one should not point out mistakes in public even if they are silly. When I completed the present analysis, I

concluded that such less than straightforward approach is the trigger for the malignancy of Indian science. Very much like various environments triggering the conversion of ordinary functional cells into cancerous cells, this misplaced sense of courtesy has induced the invasion of the body of Indian science by stupidity.

One things has to be borne in mind by every human being. To err is but human. Thus, one has popular jokes about Einstein and several colleagues with Nobel Prizes failing to correctly calculate the decrease in remuneration to be paid in accordance with new government regulations. Lest people have a wrong idea that I am always pointing out errors committed by others, I will point out several of my own mistakes.

The first example was in my B.Sc practical examination when I completely forgot that the tension in the wire of a sonometer has to be calculated in units of force (Newtons) and not in the weight (Kgs.) attached to the wire. Even when I was getting a silly number for the frequency, I was unable to identify the error and make the correction, multiplying with the acceleration due to gravity. The limited time available in the examination added to my despair till my teacher hissed in my ear (very much against the rules!). I had first used the sonometer six years earlier in the higher secondary laboratory!

The problem with self correction of mistakes is the enormous time it takes and wasted effort. During my higher secondary chemistry lab, one of my friends was having difficulty with the confirmation test for the nitrate radical. Sulfuric acid is the reagent used and tongue in cheek, I advised him that the sulfuric acid available in the laboratory was diluted and he could use nitric acid. He fell for it, but gave me hell few days later when he realized that nitric acid had the nitrate radical and hence should not be used to confirm nitrate.

During my research career, I found a senior scientist seriously discussing with a technical officer, grumbling all the while that the results do not make any sense. They were trying to electro deposit a semiconductor at a higher voltage but the resulting film looked exactly like the one deposited at the lower voltage. I checked the system and found that the volt meter was in the power supply and the current employed was the same in both cases. To increase the voltage they had put a resistance in series. When I pointed out, the senior was most upset at the silly mistake he has made but was thankful that only one day was lost! It does take time to discover a mistake even if one has the inclination to be critical. But our attitudes in India dampen any such inclination. In the class room, one knows what to expect and so it is clear that one is making a mistake. In research one does not know and so we need to be extra careful.

I have personally fared much worse, particularly while trying to prepare project proposals. There was a time in the early nineties when the key issue in MOS devices was the gate dielectric. The problem was that the silicon dioxide which is normally used creates few defects but has a low dielectric constant while materials with a high dielectric constant created too many defects. I was aware that many researchers were investigating and publishing work on high dielectric constant materials without being able to remove the last traces of the silicon oxide and not getting the proper interface. So in my enthusiasm, I came up with the idea of a sandwich dielectric consisting of both a thin silicon oxide for lowering defects and a layer of high dielectric material.

This of course was absurd. Physics does not work that way. I should have remembered that two capacitances in series result in one with lower capacitance than either, unlike resistances where if two are in series the total resistance is higher. After all, it is higher secondary physics. The problem was that several of my colleagues

to whom I mentioned the idea never pointed out the stupid mistake. I went to the Rensellaer Polytechnic in USA on a fellowship for a few months and the first person to whom I mentioned the *great idea* promptly told me how stupid it was. I refuse to accept that the people with whom I interacted in India were inferior idiots. It has simply become second nature to them to never seriously listen and criticize. After all courtesy demands it!

I made a similar mistake several years later. I was then working on solar cells and was aware that the efficiency of small size solar cells was much higher than for larger cells. At the same time, the emphasis is on integrated modules, where in essence, one large cell is fabricated and subdivided into smaller ones. These are connected in series. I was also aware of the claims that automated manufacture of these integrated modules use low temperatures and lower quantities of materials and that these would replace silicon cells in due course. This has not happened over many years.

I tied up all the ideas together and jumped to the conclusion that modular efficiencies are lower because one is not able to match the cells before connecting them up. In an integrated module one has to simply connect one cell to the next one. Whenever I mentioned this, people would nod their heads and say *interesting idea* and drop the matter. Finally, I sat down and simulated the whole setup myself. Then I found that matching is not quantitatively significant. The major problem is with *failed* or completely bad cells. In the industrial environment, the processes are efficiently controlled to ensure that these *failed* cells are effectively eliminated. The only complaint I have is the number of nodding heads I encountered before I went through the elaborate effort to prove that my idea was wrong. I could have easily got a project sanctioned to investigate the interesting idea and wasted more time and resources.

This analysis finally led me to a correct assessment of why the Indian efforts in photovoltaic research were failing. The researcher is concentrating on the latest and highest efficiency numbers. This promises eye catching slides in presentations or lectures. It may even end in newspaper reports. Concentrating on the real issue, to ensure that the process changes one is proposing are robust and will have high yields is painstaking, boring and often unrewarding. The answer is obvious but it took me years of on and off thinking to get it all by myself. The problem once again is that people are utterly indifferent about other peoples work. This in my view is the result of the *courtesy demands* training.

Now a days, in my spare times I dream about a ceramic solar cell. From my knowledge about chalcogenide materials it appears to be worth a trial. It would have been easy enough to get a project sanctioned to try it. But having burnt my fingers earlier, I would prefer someone who seriously examines the idea and possibly tell me why it is a stupid rather than spend years of pottering around with experiments, generate low grade results and keep wondering if the failure is inherent in nature or is only my lack of capability.

Experimentation is often credited by the philosophers of science as the keystone of science. This is completely logical but is really a most inefficient approach. Nikola Tesla who briefly worked for Thomas Edison made a scathing remark. "If Edison had a needle to find in a haystack, he would proceed at once with the diligence of the bee to examine straw after straw until he found the object of his search. I was a sorry witness of such doings, knowing that a little theory and calculation would have saved him ninety per cent of his labor". This is the point I am trying to make. It can be claimed that I am singularly stupid or incompetent. So it is important to look at other examples that I have encountered in my research experience to confirm my claim that lack of serious and open criticism is a major problem for Indian science

I will now cite several examples in my experience as an observer or reviewer in support of my contention that absurdity rules in Indian science. One spectacular example occurred when along with a large number of other scientists, I attended a meeting in Pune, where the progress of sponsored projects including mine was being reviewed. One professor from a very prestigious research institute began presenting results of his project on piezoelectric materials when I found that he has completely ignored Poisson's ratio. When a material is compressed (in this case due to an applied voltage), it tends to expand in the two perpendicular directions. Poisson's ratio defines the magnitude of such a deformation. The expert committee that had evaluated and approved the proposed methodology of the project had simply not considered it either. While acknowledging this goof up, the committee neither recorded the mistake nor stopped the project. The only consequence was my becoming a special target for subtle ribbing for the rest of the day from the audience.

A few years earlier, I had received a project proposal submitted for funding as an Indo-French collaboration. Such proposals routinely end up on the table of the director of the National Physical Laboratory and he assigned it to me. Even a first glance showed that proposal was absurd! It proposes that a mixture of two transition metal oxides can be made to obtain materials with different band gaps by exciting the electron from the valence band of one oxide into the conduction band of the other oxide. Not able to believe my eyes, I ran to a friend and asked him how this was possible without revealing where I read it. He laughed and said maybe it is time for me to rewrite all known physics. Then I looked into the references cited and found that this great idea was listed as published. A little more digging revealed that it was part of the proceedings of a conference held at the same prestigious institution, where the professor who submitted the proposal worked and the proceedings were edited by the very same professor! I promptly

wrote a comment that this can be considered when this idea, which violates every known law of physics is ever published in a journal after proper refereeing. Of course, I have no idea if the proposal was actually funded. It might have been if some of my other experiences are any guide. It is easy enough to arrange for a second opinion and get it approved. As I said courtesy rules and often nobody cares for anything else!

Early in my career, there was a meeting to discuss possibilities of inter institutional and industry collaboration. It was of course a whim of the then director general of CSIR to include a couple of youngsters that put me in that committee. The discussion was moving along what I subsequently realized was the norm. Everyone tries to help his particular friend and if science is a causality, so be it. In order to help the electron microscope section it was proposed that the EDAX facility of an electron microscope can be used for determining the composition of thin films for the semiconductor industry. This was before the correct instruments for such a study became available at NPL and other laboratories in later years. Usually there are many layers in a semiconductor device and each is very thin. So it was further proposed that the upper layers could be sequentially removed by etching and the measurements repeated. I was aghast at this disregard for basic physics since in the EDAX facility of an electron microscope, one measures the composition several microns inside the sample. I strongly objected assuming that this would be appreciated. The consequence of my ignorance about Indian science became apparent a month or so later when I learnt that I was dropped without intimation for the subsequent meeting.

As I try to recollect such incidents I am reminded of the silly results presented in a national symposium. The researcher was adding Fourier components of an expansion of the terms of a square wave. He got some unusual results since he had not included enough

number of terms. Oblivious of the this simple truth, he was making elaborate interpretation of his results. Not one person in the audience cared to listen or question. I remember being bewildered when the son of an NPL colleague came for his summer training to work on a project suggested by his professor from a famous engineering school; to electro deposit silicon. The impossibility of this is known for two centuries.

A scientist from another famous institute told me in all seriousness that his diamond scriber would be damaged if he uses a silicon wafer with a thin metal film coated on it rather than a bare silicon wafer. He was possibly counting on my courteously accepting his explanation. I did not oblige but could not get him to acknowledge the error. I only hope that he was merely preventing my access to his instrument and not really believing it!

I remember a colleague immediately snatching the manuscript he wished to publish from my hands when I pointed out that he cannot describe a film as amorphous in the first paragraph of the results and still describe the microstructure observed in an electron microscope later. To my knowledge he did not succeed in getting that published.

I remember a colleague complaining that he was not given a promotion, excusing his inability to define a decibel in the interview. Ironically, his job was to calibrate hearing aids. I remember a senior banging his head in frustration when another colleague was pontificating about coherent light and ended by pointing to the light coming from the overhead projector as an example of coherent light. I have heard the director of a laboratory complain that he felt like hiding under the table, listening to some of the responses. But all these lamentations are in private. No one makes the least effort to be honest and critical at the appropriate time.

One thing has to be reiterated. I do not think of myself as anything other than a mediocrity. Even as I have thrown in some of my own mistakes, other may have memories of even sillier mistakes made by me. Above even that, I do not think the problems I am highlighting should be seen merely as the mistakes of the individuals concerned. They are the consequence of the failure of everyone of us to be honest and truthful to science. Very recently in a student presentation I had a great example. The student made a error of quoting thicknesses measured by an ellipsometer to an unacceptable accuracy. As I discussed in the earlier essay, I am highly sensitized to this. In order to link her measurements to the wave length of the light used, I asked her what was the light source. She replied that it was white light. That was absurd. Sometimes, in an ellipsometer, a white light source is present but the light is decomposed into individual wavelengths which are actually used. Since she appeared to be unaware of this detail and the issue was accuracy, I asked her what the band of wavelengths in the white light source was and she said 500-600 nm. Now, this is even more absurd. Even a high school student must know that 500-600nm corresponds to green-yellow in the spectrum.

When I recounted the incident to other friends, the usual question of who is responsible was raised. I responded that I was as responsible as anyone. Because I simply allowed the student who made this glaring mistake to go without any stern action. I was also following the *courtesy demands* approach, in frustration if nothing else. I have repeatedly found that any adverse decision I may take will be bypassed. I knew perfectly well that had I pressed my point, an emotional scene would have been created but ultimately no action would have been taken.

I had ducked the responsibility and failed to take action when clear cases of academic fraud have come to my notice in recent years. I saw research papers that show identical micrographs

describing them as results obtained on two different materials and from two different institutions. I had earlier taken the trouble to honestly investigate a clear case of plagiarism and report my conclusions only to find the culprit let of with a slap on the wrist and subsequently given a promotion. One has seen adverse comments in international journals regarding an Indian academician, who was caught palming off samples gifted to him during visits abroad as his finds in Himalayan exploration, being allowed to retire with full pension benefits.

Even proven fraud is not punished in India. Clearly, non-punishing of fraud has resulted in courtesy degenerating into something far worse. The multitude on the other hand closes ranks and hides the bad apples to avoid open criticism in the society, *biradari* as it is called in Indian slang. So perpetrators have no fear of negligence or even of deliberate fraud. The environment is not exactly conducive to strenuous efforts to be critical. So in recent times I try to avoid having to take a decision in the first place. Ultimately, we have those who give up out of despair, and those who are incapable of doing anything. One of my colleagues summed up this despair exclaiming, "*Is haham me saare nange hain*" (All are naked in this communal bath). Resigned acceptance has led to people not even trying to cloth themselves making it a great variant of the famous fairy tale, *The emperor's new clothes*. Unlike in the tale, neither the people nor the emperor listen when the child points to the fact that emperor is naked. One international journal continues to send me research papers for refereeing despite my approval rate being less than 5% . I of course would like to believe that they approve my rate!

As I mentioned in the preface, the greatest influence on my thinking and writing this book has been the popular writing of Richard Feynman. He describes in his memoirs how he concluded that "no physics is being done in Brazil". He asked students

questions to which they could rattle of the answers from memory but close questioning shows how shallow their understanding is. Intrigued, in association with a colleague, I tried the experiment on one of the brightest Ph. D students in NPL. I asked the same questions and got the same answers! Even the present effort to record our mistakes owes much to Feynman's demand while describing cargo cult science that one should report failures as well as successes. He was praised by many for describing in loving detail all the failed efforts he made to understand superconductivity. It has to be admitted that it is easier said than done for mediocre individuals. But the systematic failure to criticize has immobilized Indian science and it has to be broken somehow.

Actually this malaise in India runs deep. One sociologist of science pointed out in the Sir K S Krishnan Centenary issue of Current Science that the first solar cooker made in NPL was photographed with shining steel vessels being used instead of vessels covered with black absorber layer as they should have been. The cooker could never have worked despite claims that visitors were served food cooked in it. Obviously, it is stupid to think that the great scientists starting with Sir K S Krishnan were not aware of the physics. This mistake can be ascribed to some unknown juniors. But even here the association with the societal disease is not admitted. What were the seniors doing? Why did not they spot the mistake?

It is of course silly not to list the mistake of Sir C V Raman in this context. Raman himself, despite being the greatest scientist India has produced failed to appreciate the strength of the theoretical ideas he was challenging with his explanation of Raman effect in diamond. The intricate physics question of whether Raman was at least partly right has been addressed by G Venkatraman in his masterly biography *Journey Into Light*. But these incidents show that the greatest of Indian scientists share with their mediocre

countryman, traits of being resistant to criticism and reluctance to openly admitting mistakes. It is said that words which are merely indiscretions of ordinary men are blasphemies in the mouths of priests. So to find so easily, these examples from the leaders of Indian science is extremely painful. It forces one to admit that most Indian scientists exhibit this particular undesirable trait. The argumentative Indian of Amartya Sen is more correctly an undisciplined Indian who loves to divert any criticism by pointing to other mistakes and these indiscretions by the mighty come in quite handy not to reform but to justify oneself.

Belief in crackpot science is quite common in even in the so called advanced countries. Achieving complete literacy has not reduced blind acceptance of crazy ideas anywhere in the world. In the west, it is commonly conceded that most scientists are atheists but most Indian scientists are not. Perhaps the more flexible Hindu religion contributes. I am very interested in the conflict between the roles of science and religion in life and admit being not an avowed atheist. But my experience has been that acceptance not of some form of spirituality but crazy god men and even astrology is quite common among Indian scientists. Belief in the fear of radiation from mobile phones or extremely low pesticide residues or in the efficacy of unproved medical systems like homeopathy is common the world over. However, outside India, scientists are more skeptical of these. Indian scientists are not only very gullible in such matters, they are not embarrassed in the least for these opinions. The belief in wildest conspiracy theories is also quite prevalent. Only an Indian scientist could challenge me with "Why should everything be proved by the standards of modern science?".

Neils Bohr, the great Danish Physicist is often quoted as having said "Of course I don't believe in it, but I understand it brings you luck, whether you believe in it or not" in reference to a horse shoe on his table. In reality, there is no evidence that Bohr

actually said it. But most Indian scientists would not even qualify their superstitions by saying that they do not believe in it. Some of my senior colleagues seriously tried to convince me of the scientific validity of the *astras* described in mythology, comparing them with atomic weapons. The liberal media is justifiably excited about the support for illogical ancient science ranging from God Ganesha with an elephant face as an example of plastic surgery to designing airplanes using the ancient texts. They rarely concede that this malady has been in the making for a long time.

Separating the real accomplishments of ancient Indian science from metallurgy to mathematics grain from nonsense is relatively easy if one is intellectually honest. I emphatically attribute the current unwillingness to be intellectually honest and critical to the courtesy syndrome. A look at the Indian roads will convince us however that Indians do not value courtesy and a short conversation will show how critical they can be when they do not get what they claim to be their due! So this courtesy in Indian science is more correctly an excuse for incompetence.

I will now highlight an area where this conspiracy of silence has already become a major problem. In the years following independence, the socialistic policy demanded that the public sector should command the heights of the economy. Universities and other institutions offering higher education were almost totally financed by the government as they were before independence. There were private colleges affiliated to the universities but these rapidly became *de facto* government institutions following the demand of the employees for parity in salaries and pensions with the government run institutions. Over the last twenty five years, private institutions in higher education have made a big comeback.

For the present discussion, socialistic concerns regarding the right to education and undesirability of the rich buying advanced

degrees are not relevant. The norms of the day make institutions offering master's and doctorate degrees entitled to the title of deemed universities. They then become independent of supervision by government universities. So research without facilities and/or giving degrees without basics have become very common. Consider an institution offering a master's degree in an interdisciplinary area. This is a favorite approach since the course content cannot be compared with other established institutions and exposed for the fraud it often is. In order to get enough applicants, students with many different majors in the bachelor's degree are admitted.

This creates problems. For example, a student with a bachelor's degree in computer science has not studied physics at the advanced level and a student with a masters degree in physics has not studied computer architecture. If these students are to be taught and evaluated together, content of the so called interdisciplinary course cannot be really at the masters level in either branch. It does not require a Nobel Prize to recognize this. In a standard university with many departments, the students can be asked to take the required core courses from other departments, at least in principle. In any good institution this would be rigorously enforced. But many new institutions offer masters degrees in one or two disjointed areas. So they have no such capabilities. *Courtesy demands* that one not look too critically at the course content. If students end up unemployable, the employers must be forced to be considerate. After all it is not the student's mistake! Again and again one sees lamentations in the popular press about the adverse impact on students because some institution or the other has not been *recognized*. So these institutions cannot even meet the lax standards demanded!

The consequence of an ill trained student in the technological market place is bad enough. But it is absolutely catastrophic in the research and science arena. One of my dear

friends put it in a classic summing up that we colleagues have been repeating to ourselves endlessly. He intoned. The most hardworking and intelligent want to do an MBA and earn money, Of the residue, some become doctors and of the residue some decide to go to USA. Of the residue of the residue, some aspire for the IAS. What should one expect from the residue of the residue of the residue of the residue…….

It has become rare for the brightest in the school or in the higher secondary examination aspire for a research career. If they rarely do, they emigrate to greener pastures outside India. The weaker students somehow manage a master's degree of the kind discussed above and aspire to do research. The *poor faculty* of the research institutions need *quantitative proof* such as the number of students guided for Ph. D. and the number of publications for their career advancement. So they take on this responsibility of providing an opportunity to these students. Demands of courtesy are so ingrained that no one questions such approaches.

The above may sound extremely wild extrapolation from selectively remembered anecdotes and challenged as biased or worse. After all, Indian scientists continue to publish in international journals, attend conferences abroad. Large numbers manage to work in the advanced countries. Science was neglected by the colonial government which was interested only in converting Indians into clerks. The government of independent India has invested in science, though for obvious reasons it cannot match the advanced west. There have been many success stories ranging from individuals who are internationally acclaimed to atomic power, nuclear bombs and the latest accomplishment, space research. Extreme criticism and meritocracy arguments are mostly a covert challenge to the half hearted efforts to implement social justice. I will comment on some of these arguments, as I undertake a realistic essay.

World over, there is a general feeling that empathy and sympathy should dominate over more mundane issues such as merit or accomplishment. Thus, every educationalist worth his salt demands that students be treated circumspectly, that criticism would lead to psychological trauma for the child and that competition is not desirable. Those who oppose are labeled variously as conservative, heartless or hidden racists. In the present context however, it has to be admitted that India extends to research what other countries do in the primary classes.

I was reprimanded by one of my professors during my Ph. D years, for stressing some point about merit saying you cannot realistically expect a poor *dalit* student to match your knowledge content. This fear of caste based nepotism and other efforts to derail social justice lead to rules in the Indian science establishments whereby the selection and assessment committees are at least on paper not independent. The decisions are expected to be proved correct beyond any reasonable doubt. Thus, a demand for an objective indicator of research quality is very acute in India. A hope that this would help identify, support and encourage economically and socially relevant work is often expressed. But primarily, fear of nepotism, particularly caste based nepotism, leads to demand for objective criteria for all evaluations and hence numbers are cited either to question decisions or to support them against social justice claims. Thus, it is best to understand the extreme limitation of these quantifications, number of research publication, citations, impact factors and so on. This is also necessary for appreciating the approach of evaluating Indian science I employ in the next essay.

Consider the number of research publications emerging from India. The first question is whether the number of publications and other quantitative measures of research quality have any significance. One important issue about international journals is

never highlighted. Their number has been growing for quite a while. Over the past thirty years, one has seen the number of articles in journals increase tremendously. Feynman says there was a time when he could read each article in physical review since it was so small! Today no one can read all the papers published in a journal, even if he were so inclined. For that matter, even reading all the papers published in ones own narrow area of work would be too difficult. So one has to be selective and here reputation of the individual or the institution where he is working will often be the ground for selection.

I was a witness to an amusing interaction in this line. In the late eighties many theoreticians were competing to provide a theory for the newly discovered high temperature superconductors. A professor working in a world famous institution came to give a talk on his theory. One NPL scientist commented that there was one paper in published literature that completely contradicted the theory. The professor casually responded that he does not care for the experimental results of all and sundry and accepts only the results from some groups! Many in the audience were angry at the cavalier attitude. But such apartheid exists and it is not completely illogical either. Is it really so very difficult to get unreliable results published?

The ever increasing journal numbers and pages make publication of what I term *so what research* very easy. What these publications indicate is that one has some experience in performing certain scientific procedures and operating certain equipment. Not that the results are of any scientific consequence. The mere fact that the paper has been published after refereeing does little to ensure it utility and the refereeing standards are ill defined at best. The policy of many referees is not to bother too closely since eventually the truth will come out. That is to say, if the startling claims are false they will not be reproduced and hence die out.

This is the standard logic of market economics. Eventually the market will return to equilibrium. No economist however has quantified time and the response by the famous economist Keynes "in the long term we are all dead" is very popular. In the context of science, since most scientists have only limited time and resources, no one repeats the work unless you already have reputation. Knowing this, the people publishing the work are emboldened to make even more unjustified claims just so that the paper is published and immediately move to another area to repeat the policy. They can use the quantitative indicators to justify themselves for career advancement.

There is one additional malaise peculiar to the Indian science system. Almost everyone who has participated in science research and published papers ends up in the academic institutions or government research laboratories as the absorption of such people by the industries is minuscule. So the number of publications increases in geometric progression just like population.

Counting the number of papers has been supplanted in recent years by counting the number of times a particular paper was referred to or cited in other publications and also the *impact facto*r of the journal. I find this numbers game most amusing. A very senior scientist told me an amusing incident from the era when numbers were not too important. A colleague of his had excitedly told him that his paper was cited in the latest publication by the world leader in the field. Knowing the quality of the work, the senior scientist was totally surprised and ran to the library to find the following gem of a reference. "In view of this, the results published by….are most certainly wrong". Well!, that is still a citation and is counted! A statement of the type, "this area has been extensively investigated in recent years" is very common in research publications. It is followed by some twenty references. Is there any relevance to these numbers?

One takes pride in the journal impact factor which is the number of citations a journal receives in a given year divided by the total number of articles published in the two previous years. A completely arbitrary number. I selected for analysis a single issue of a journal, ten years old and counted the citations for each paper. This is easy to do today since the data is in public domain. I found a few papers being cited hundreds of times, several in single digits some never. This is called a long tailed distribution and any average defined is completely arbitrary and valueless. So is the *impact factor.* It does not reflect not the citations of the papers published in the journal in any way. How can any scientist proudly claim credit with a straight face for the publication of his paper in a journal with a high impact factor?

My close friend published a paper in *Physical Review Letters*, a very prestigious journal and the paper has no citations. On the other hand, a paper I published, twenty years ago in a far less prestigious journal called *Solar Energy Materials and Solar Cells* has two hundred citations. As a measure of the effort, quality or utility, both numbers are useless. Everyone accepts in private that quantification statistics of the quality of science are silly. Everyone has heard the famous statement popularized by Mark Twain. There are three kinds of lies: lies, damned lies, and statistics. But in public, statistics are extensively employed to buttress ones own position.

Quantification is the easy target for self justification that is encouraged with a hope that it serves social justice. Social justice has another component in the Indian scene, preference for the *local candidate*. Just as the *dalit* or other backward caste student needs to be given a handicap, students from institutions with limited facilities have to be given a handicap! Consider a teacher in a college teaching undergraduate students. Obviously he has no facilities to perform research. But that is not his fault. So we must bend rules if

necessary to provide opportunities for promotion to become a professor. If someone in these places performs low grade work he should be applauded for doing something in the difficult working conditions and should not be criticized. In this competition for being labeled backward and given protection, even the best institutions in India participate. One has only to look at the amount of inbreeding; hiring for faculty positions students who studied in the same institution to realize the level of malaise. This prevents infusion of new ideas but then *courtesy* has been so ingrained in the psyche that any criticism is taboo.

The limited utility of research publications explains the so called success of individuals when working in the advanced countries, which is often a counter argument for any criticism of Indian scientists. Feynman while discussing physics in Brazil comments that science can be learnt by rote. Research can also be done without any understanding! Trained hands are very useful and can be conveniently offered credit in lieu of money. This is the reason we give doctorates to students with low intellectual capability as mentioned above. But this problem is not wholly Indian. A professor told me very early in my research career that his students knew not only to operate an electron microscope but also to maintain it and are thus in great demand abroad. He added tongue in cheek that a post doctoral fellow is much cheaper than a technical engineer to hire there.

So people may not be creative and still contribute. But the system must have the resilience to prevent them from climbing the hierarchy and making invalid claims. In the Indian context, any challenge of this type will be met with a demand for proving beyond doubt that the criticism is not biased to ensure social justice. Over dependence on the numerical indicators are the consequence. Despite all the socialistic concerns regarding IQ tests, and accusations of racial prejudice, high general intelligence is

absolutely essential in advanced research even if it is not sufficient. I do not think social justice and creative science at the highest level can coexist. Contemporary Indian society should be aware of the extent to which the desire for social justice and courtesy demands have been counter productive, resulting in wasted resources. Extending the spirit of Mössbauer's comment at the start, society can decide the quantum of support it wants to provide to science, keeping in mind the *winner take al*l nature of scientific activity and the objective reality of the failure of Indian science as discussed next.

IV
If so rich why so poor

The title of this essay is taken from a Mexican saying "If so rich why so poor, if so poor why so rich", mocking at people pretending to be rich. If you are really rich why is the wealth not visible in your life style. If you are not, why are you pretending to be? So it is with a realistic analysis of Indian Science. Nowhere is the old adage that imitation is the sincerest form of flattery more true than in science and technology. The Nobel Prize in Physics awarded in 2014 to the inventors of the blue LED offers a great lesson to anyone interested in evaluating science and technology.

The original research papers describing the advances were published in journals with very modest impact factors. The strength of the work lay in its robustness. Their recipe of using a low temperature to initiate the growth and high temperature subsequently could be used by anyone to grow Gallium Nitride suitable for LEDS. The idea itself may be very simple and may not have been a consequence of a great critical insight. But it could be replicated very successfully. The value of any new advance in either

basic science or technology lies in its usefulness for others. If a basic physics idea is really revolutionary it will be immediately snapped up by the research community. If a new technique of producing some object emerges, it will be immediately copied. Technologically significant work does not always result in financial benefits. While one thinks of patent rights as some kind of a gold mine, the greatest invention in modern era "the transistor" did not make billions of dollars in license fees for the American Telephone and Telegraph company.

A few points have also to be kept in mind. To begin with, despite the reservations of most Indians, science is a winner take all human endeavor. C V Raman reported his findings about what is now universally called Raman Effect a few weeks ahead of scientists from the soviet Union. Few remember their names! After all who knows the man to climb Mount Everest after Hillary and Tenzing and who cares? Further, if the work is worth anything, it should be explainable in a few sentences understandable to everyone. As Winston Churchill said, "All the great things are simple, and many can be expressed in a single word: freedom, justice, honor, duty, mercy, hope". One of my senior colleagues grumbled when the director gave him ten minutes to present the work done by his group in one year. I gently pulled his leg by pointing out that ten minutes is sufficient to explain the special theory of relativity.

Complexity in expression and claims that it one needs expertise to appreciate the accomplishments are efforts to dress mediocrity in the grab of excellence. Both good science and successful technology are easily identified. However, Indians have developed a new "reality control" worthy of George Orwell's novel *1984*. This is called technology demonstration which is not science since it is a replication of what has already been proven to be feasible nor technology since it is not meant to be replicated!

I propose to make a realistic assessment of the state of science, technology and this hybrid entity, technology demonstration in India. What have the people of India got as return for the investment of public resources. One of my directors remarked that the amount spent on our laboratory is not even comparable to the cost of a single visit of the prime minister to a foreign country. Another famous scientist made a derisive comment that when you offer peanuts we can only attract monkeys. The doyen of Indian science had gone on record many years ago saying India has third rate science and fourth rate technology.

The scientist seeking funds for his research, as with any other human is never going to be satisfied with any amount of money. But one thing cannot be questioned. The expenditure on science and technology in independent India is vastly more than the paltry sums our British masters were willing to spare. So the differential of facilities must surely have decreased.

Having spent forty years in science and technology one cannot but admit that the laboratories are better equipped today. Many visitors from the so called advanced world concede that the facilities available in some of our premier research institutions are superior to their own. I have personally argued that when comparing scientific work of two individuals the resources expended have to be taken into consideration.

It is my experience and many of my friends concede *in private* that they were most productive when resources are meager. In line with the narrative in earlier essays, this would not be accepted in public. They continue to offer *lack of resources* as the excuse for lack of achievement. So it is pertinent to ask whether the status of Indian science *vis a vis* the international scene has improved as a consequence of the increased spending on science since independence.

One article published in the mid eighties was provocatively titled, Indian physics before and after independence. It was received with lot of consternation by most senior science academicians and the author was the recipient of much acidic response. While I was the audience to many such harangues, I never had the pleasure of actually reading the article. Despite the most diligent use of the Google, I was unable to trace it. The synopsis as it was relayed to me was; ignoring Raman effect, a one of a kind thing, there were several seminal contributions of Indian physicists before independence. There were formulae named after the scientists like the Saha (ionization formula) and Bose (statistics). There were experimental procedures pioneered by Indians which were used by the others like Krishnan's work on diamagnetic crystals. Nothing comparable can be seen in the post independence era.

The author was damned one side up and the other side down as being completely ignorant of contemporary science and its mode of functioning which is far from the sealing wax and string approach of the earlier era. The analysis which follows here owes a debt to those discussions. More so in view of my inability to trace even the name of the author of that article.

In the late nineties, the NPL library procured a set of volumes called Physics in the twentieth century. The six volume set was beautifully written and while it was too big to study entirely, I dipped into the sections dealing with research activities of my interest. An interesting fact emerged. The book contained a name index where every individual named in the volumes and all authors of cited publications was alphabetically indexed. This reignited my interest in the earlier controversy regarding Indian science and my regret of not having been able to read the article in question. Indian names are quite distinctive and I decided to lookup in the volumes every Indian sounding name in the name index. I was aware that several names from the minority communities may have

slipped through but felt that this was a minor issue since the strength of conclusions I draw would in any case be very limited.

I was astounded by what I uncovered. The well known pre-independence heroes (Raman, Saha, Bose et al) were all there. I uncovered some that I was not aware of, the pioneering work on the resistivity of liquid metals by Bhatia and Krishnan for example. There were many Indian names of the recent years but invariably citing work done outside India. There were a couple of names like the liquid crystal expert S Chandrasekhar named for their having contributed to the area without any specific result being mentioned. So the anecdotal claims of the earlier author were proven to the hilt. Perhaps Indian physics also became independent along with India; independent of any desire to be significant or perhaps it decided to renounce fame and be more egalitarian.

Nearly fifteen years later, I chanced upon a supplement from the Nature group of publications which made a scientometric analysis of all papers published in all their professional journals for that year. Amused by the number of contributions listed as originating in India, I checked the numbers more closely. After ignoring all the letters to the editor, comments about social issues and articles which provided a statistical analysis of data provided by ten or more institutions including one or two from India, I was left with a grand total of two research articles from all the Indian academic institutions together. Not very surprising. The last time an article was published in that prestigious journal from the National Physical Laboratory was about fifty years ago. Thus far, an effort to evaluate the "academic science" being done in India uncovers only its poor quality.

There is an amusing corollary to this desire that reveals the depths to which Indian science has collectively sunk. A special "*Nature India*" has been created by the publishers. This, unlike the

other prestigious Nature journals does not publish refereed research work. The publishers would not want to dilute their standards. Nature India is a news magazine that provides synopsis and comments about research publications by Indian scientists in other less prestigious journals. It is par for the course for Indian scientists to include this *citation* in their quantitative research appraisal so that the list of publications includes some item with a name tag of Nature and hopefully someone would mistake this for a real publication in Nature. That the publisher does this exclusively for India is a significant comment on our collective moral standards in science.

One interesting interaction with a former director of NPL springs to mind when one reminisces about Indian science and professional science journals. That was an era when the senior Indian scientists were genuinely interested in creating high quality Indian journals where Indian scientists would publish. They were trying to follow the soviet scientists in this regard but the results were pathetic. This senior Indian scientist caught hold of me in a social gathering, then a fresh entrant to NPL with a question. Why were the Indian journals not making progress? Possibly he was just evaluating my ability to analyze things. Maybe he was just thinking aloud. I responded by saying you are responsible. I understood the greatness of the individual when he politely asked me how? I stated what I then felt was the answer. I told him that you treat us like your own children and insist on publishing whatever we produce. You are hoping that this would act as an encouragement but it actually results initially in complacency and ultimately in incompetence. I realize now that was only a partial answer. Creating a world class journal is perhaps more difficult than even creating a world class laboratory. If standards are held too high there will be no papers to publish in this unknown journal. If they are lowered the journal will not be great. A classic chicken and egg conundrum.

Indian media today endlessly speculates and pontificates about the world ranking of Indian academic institutions. There is always someone who includes the Indian Institutes of Technology or Indian Institute of science in their lists. The media does not report that these lists are made mainly to help the students who apply for admission to decide how competitive their credentials are and if they have any chance for admission in a particular university. Ranks bordering on the three hundred or four hundred for institutions in India are bandied about.

Do such ranks make the least sense? Can one rank anything or anyone to such accuracies. Who is the world's 300th best sprinter or cricketer? Is he really better than the 350th ranked individual? Really!!! It is always possible to place some numerical value on the financial assets, number of applicants, and quality of faculty but it is silly to even think of this as a sensible system. One already knows that MIT, Cambridge University or Stanford University are among the best and since the lists also place those institutions at the very top, one feels these rankings are sensible. But the lists are silly and talking about Indian institutions in the fag end of a list is nothing but nonsense.

In fact we do not need to go far to realize that our institutions are pretty mediocre. One fact alone seals the argument. The media highlights the enormous salaries offered to a few students in these institutions during campus placements. The most pertinent fact that is carefully hidden is the inferior pay packets offered to the master's degree holders. If the industry at large was paying for the training in these institutions, the higher degree should earn more respect. This is true for any American university. It does not hold for Indian institutions. B. Tech. students get the record pay packets not M. Tech. students. MBA's are also paid handsomely but it is mostly the students from IIM's who get that credit. In all Indian institutions, there is an unacknowledged differential between the bachelors,

masters and doctorate programs; with the highest degrees being the weakest. The jocular description of "residue of the residue" mentioned earlier is also applicable to the Ph. D. in IIT. A former director of an IIT, Prof. Indiresan was among the few who frankly and openly admitted that the quality of the B. Tech. degree holder from IIT lay more with the quality of the student. The IIT entrance is the toughest exam to crack as is the IIM entrance because one has to select a minute fraction of the aspirants. The toughness is not an idiotic fancy of the faculty nor an ingenious device to subvert social justice. It is a necessity forced on them by the statistics of a Gaussian distribution.

Pandit Nehru, The first prime minister of independent India called the river valley projects the temples of modern India. If actually asked there is little doubt that he would have called the various laboratories and science departments created by the government of India as temples too. Perhaps the name is appropriate. Temples in India house a stone figure which is adorned with gold whenever possible. Their utility even for the believers had been challenged for millennia by the saints and scholars. Let us consider some of the most high profile examples of the failure of this post independence belief that excellence is largely a matter of resources and thus creating systems is a laudable goal.

The first example is the green revolution. India recovered from the tragic food shortages of the sixties. Acceptance of the American aid in the form of PL-480 wheat which provided temporary initial help is still vaguely if somewhat grudgingly remembered. We have completely forgotten the Prime Minister having to appeal to Indians over the radio to fast for one night in a week. India has transformed into a food surplus country. We only ignore the significant fraction of the population which is still malnutritioned! In any case, it is commonplace in the news media to describe the transformation of India as an accomplishment of

the Indian scientists. One does not even hear a murmur from the scientists that this gratitude be better directed to the real contributors. All the seed varieties that made this impressive increase in crop yields in about one decade possible are imported. The only work done was to distribute the seeds to farmers, collect the crop and scale up the utilization. Hardly a scientific accomplishment to crow about.

It is interesting and perhaps embarrassing to remember that in the initial years the rice varieties were referred to by the IR Nos. of the International Rice Research Institute, Manila. Subsequently however, these were given Indian names. There will be howls of protest that these are *much improved* Indian varieties. The rest of the world is of course biased and hence sees no reason to use these or credit Indians for them.

The recent environmental concerns regarding the use of genetically modified cotton and other vegetables also concerns imported seeds not Indian creativity. The key issue for the present is not the ecological factors but the deafening silence about the source of intellectual credit for the green revolution. The only problem in the above example is the issue of intellectual honesty or lack thereof. The farmers have delivered and India has a surplus of food grains. The cost to the country has also been very minimal.

As the next example, we turn to the Indian efforts in the defense sector. Two major projects spring to mind. The development of the main battle tank (MBT) is one, the light combat aircraft (LCA) is another. Both were launched with fanfare around the time I started my career. What one has after thirty years are a couple of demonstration aircraft which fly but as of today have not participated even in any army exercise! The army had to be literally arm twisted into accepting a few of the tanks. The efforts at developing these have been very costly and the reality of failure is

too big to be totally brushed under the rug. But there are enough murmurs about the necessity to support indigenous effort to keep such projects going

A key question is never asked because of the usual problem of courtesy. Why do we attempt these big ticket projects when the small arms used by the defense services are all either imported or built under license? After all it should be easier to build these than the complex MBT or LCA? There are nearly fifty institutions under the Defense Research and Development Organization (DRDO) and everyone of these will display prominently in their annual reports, their contribution to the defense forces. One question is never once again asked seriously. What is the net value of these items procured by the armed forces? What fraction of the procurement budget do they represent if we ignore common place items like clothing. What fraction of the output of the various ordnance factories is based on this research? The demands of courtesy in this a case are aided by demands of secrecy and nationalistic pride!

To understand the failure to commercially produce the MBT and LCA one has to discuss the accomplishments of the Department of Atomic Energy (DAE). The main direction of the program was set by Homi Bhabha in the early fifties. It was perfectly logical and inline with the mantra of self reliance. Since India has few resources of uranium and plenty of thorium we should start with reactors using natural uranium. Then use the plutonium produced to produce power and also convert thorium into usable form of uranium. Finally breeder reactors will produce more fuel from the thorium than they consume to generate power. So the complete industrial requirement, from the mining of atomic minerals, processing of fuel, producing the heavy water and building the reactors had to be setup. In addition to this being a uniquely Indian approach, the embargo on cooperation in the atomic power sector left India with no option. At first glance this seems to be a success story of Indian science

and is so claimed. About sixteen power plants have been setup and operating. Another six are being setup. And India has been recognized politically as a nation with atomic bombs.

Today, the largest atomic power plant is the one set up with Russian collaboration. There are endless debates about the liability rules of India that prevent Western suppliers from investing in the sector. The key issue is not the desirability or otherwise of India trying to establish reactors with foreign collaboration. It is not even the more recent argument about the liability of the suppliers in the event of failure. It is not about the environmental concerns that have seen most of the advanced world turning away from nuclear power as an option or of local people even in India agitating against them. Just for the record, fully a third of the reactors being built in the world today are in just one country, China, where public opinion is not an important issue. The question for us is what has actually been accomplished by DAE over the years and what is the lesson it offers for understanding the failures mentioned earlier.

The Indian atomic scientists have successfully reverse engineered the Canadian design for the pressurized heavy water moderated reactor (PHWR). They even managed to increase its size from the original 200 MW to 600 MW and plan to increase it to 1000MW. However, Bhabha's original target of 8000 MW of power from atomic reactors by 1980 is not going to be realized even by 2020. The limitations may be both economical and logistic. The available technology for the pressurized heavy water reactor is possibly commercially not competitive. Thus, it may not have been possible to raise the funds on a commercial basis and expand the program. Alternately, there maybe other limitations for expansion like the availability of the fuel. As a technology demonstration the Indian PHWR is a success. Equally clearly, technology demonstration may not automatically result in commercial technology.

The envisaged second and third stage power generation program using the thorium route is a major failure. The initial prototype breeder reactor was scrapped without ever being operated and while a bigger one is being built, the program is very much behind schedule. Yes, the technology is very complex and very few breeder reactors are operational in the world. So perhaps, contrasting this failure with the reverse engineering of the Canadian design may not be totally fair. But this is precisely where creativity and excellence is to be demonstrated, not in reverse engineering! The government and the people will continue to support the work for patriotic and political reasons. But, that is not demonstration of excellence.

It is unquestionable that ISRO, just like the DAE example cited above has successfully reverse engineered rocket launch systems. But there is little to support claims of great accomplishment. Matching the recent publicity for the Mars mission, a few years ago, there was huge media praise for ISRO which was said to have discovered water on the moon. A little research showed that the presence of water on the moon was known earlier which the present study confirmed, that ISRO had little to do with it other than launching the satellite for NASA and that the results when published in a prestigious journal were not authored by the ISRO scientists, once again demonstrating the Indian desperation to claim credit irrespective of reality.

Actually, the fact that the paper was published is itself a surprise. As Feynman pointed out, there is very little high quality science that can be obtained exclusively from space missions. The successor to the Hubble space telescopes being built now is terrestrial. High speed terrestrial communications have further eroded the utility of space communications. Just as nuclear power is not acceptable for environmental reasons, space science is no longer a novelty or priority in the advanced world!

The recent publicity about the Mars mission has also to be critically examined. The ISRO Mars mission, Mangalyan, is acclaimed to cost ten times less than that of the others, at least in the media. A wag on the internet reproduced the hazy picture of the Mars released by ISRO and quipped that if they had spent more money they would have got a sharper picture. As usual this was attacked online by a large number of my patriotic countrymen.

But seriously; was low cost the pre defined goal? Why should that be an acceptable target? It is not, unless as many assume, all satellite launches by India would be similarly priced and India could take the business of other nations and emerge as the next space power.

But as the history of the atomic power reactors mentioned earlier showed, scaling up the launch schedule to make ten times more launches is not assured. In fact there are no such official claims by ISRO. In the absence of the financial justification, the demonstration looses much of its glamour. What has been accomplished is repeating something done more than four decades ago. One should not make the mistake of placing the target around the arrow wherever it has fallen and then claim bulls eye. Is that the case of these financial claims? Was the financial claim highlighted *post facto* since there was no other targets worth mentioning like the water on the moon highlighted earlier?

In any case, who audited the expenses of ISRO and came up with these figures? The sad reality of Indian government economics is that no one knows the cost of any thing. There are similar claims about the lower cost of power generated by Indian atomic reactors as opposed to the imported ones. I have time and again found Indian scientists making tall claims regarding the cost of technology being developed without the least idea of how to properly account for the manpower costs, contribution form fixed

assets, servicing etc. Some hilarious consequences will be discussed later but financial claims in Indian science have to be swallowed with a very generous pinch of salt.

Incidentally, in the Indian scenario, no one questions if targets mentioned for fairly large projects are sensible. One interesting experience is worth mentioning. In a visit to the Indian Tokomak Facility, a senior scientist showing me around mentioned that this was the only facility in the world designed to operate ten or more times longer than anywhere else. The silliness of this ingenious claim became apparent when I asked him how high the plasma density and temperature were. He then shrugged and admitted that they were very low and hence even the long time duration does not make the density temperature time product close to unity as required for a really challenging tokomak. That such a soft, completely irrelevant target has been approved for a costly project shows how uncritical our science planners are. The matter of fact way of making the claim (the senior scientist never expected the question) shows how ingrained our courtesy culture is. The very fact that we have a tokomak is a matter of pride and its utility is not apparently relevant.

Sometimes, there are reasons other than science for supporting some programs even if they are not scientifically robust. The Antarctica missions are an excellent example. The real necessity for this program is political, to join the international group. Oblivious of the general awareness of this reality and of course counting on the listeners to be bound by courtesy and not raise awkward questions, participants routinely claim great credit for mediocre work done in these expeditions.

The failures of the defense research efforts as illustrated by the LCA and MBT mentioned above make sense in the light of the successes of ISRO and DAE. In the case of defense procurement,

time schedules are strict. As mentioned above, failure to meet deadlines did not matter for the DAE program. Tanks and aircraft are commercially available and are being continuously improved. Cost and performance comparisons are available. If one manufacturer makes an unrealistic claim, others will point it out! Also the numbers are large. One cannot have the luxury of continuously tinkering with the next space launch or the next atomic reactor.

When one talks of technology it is not a demonstration that counts. It is the ability to deliver the package. The popular fiction writer Nevil Shute categorized an engineer as a man who can do for five bob(shillings) what any bloody fool can do for a quid (twenty shillings). So economic and commercial success defines technology. When viewed in this light, I have a very negative attitude about the so called accomplishments of Indian technology demonstrations.

Even more important, I have serious misgivings about the missiles and nuclear bombs said to be in the Indian arsenal. In defense, reliability and the confidence which this generates are absolutely essential. The weapon has to function precisely as expected and exactly at the time when it is employed. There does seem to be an attitude of confusing between demonstration and usability in the minds of the Indian intelligentsia, the government and the general public.

The general atmosphere of courtesy and secrecy makes it difficult to ask difficult questions and get any responses on this crucial issue. Our unwillingness to admit to the limitations of our accomplishments and their utility in the science and technology arena matches our reluctance to close public sector undertakings and banks even after the socialistic approach has proved to be a failure and the country forced to change the policies.

The prime minister of India inaugurates the annual session of the Indian science congress. This is a unique annual ritual that has been going on for sixty years and reflects the Nehruvian idea of science as the vehicle for transforming India. As usual Raman made an acidic remark that he would not want to attend a meeting annually inaugurated by a politician. That Raman was right in complaining is borne out by the number of Indian science meetings, big and small, that are inaugurated by politicians and bureaucrats. Clearly, the senior scientists prepare the speeches to be read out by these non-scientists. They are invited with an eye on the largess provided through government grants and their role in selecting directors of government institutions. Courtesy rapidly degenerates into sycophancy. Should we wonder at the inability of senior scientists to stop the nonsense about ancient Indian science being spoken by the political class? We also need to remember earlier instances of such spinelessness during the era dominated by socialist nonsense parading as intellectualism.

As a sad daily reminder of this bitter reality to me, the walls of the National Physical Laboratory are prominently adorned with more photographs of politicians than of scientists. A hilarious example is the representation given to politicians of the erstwhile communist countries who are probably reviled if remembered in their own countries.

The average Indian probably regards my analysis as merely bad implementation of an essentially correct idea. It is *obvious* to them that the progress of a poor country like India is only possible with science. I question this consensus. As usual it is Feynman who provides the correct way to analyze these problems. Feynman described the situation on the heights behind the Copacabana beach in Brazil in the fifties. The heights housed shanties and the poor people living there came down to collect water in buckets from the luxury hotels being constructed on the beach. This water eventually

flowed down the heights in the form of sewerage. A typical problem of the juxtaposition of the rich and the poor. The solution to the problem is difficult or easy depending on one's political philosophy. It however does not depend on science! The science or more correctly technology needed is very old.

Empathy is a great human character. A scientist or educationalist can really contribute by donating his personal money and time. But dreaming of reorganizing science into a path of utility for the downtrodden, however noble, is an exercise in futility. I am reminded of the center for Application of Science and Technology to Rural Areas (ASTRA) at my alma mater IISc. When evaluating the utility of such centers in our institutes of advanced learning, one fails to calculate manpower and other costs. One also does not examine if these socially relevant problems are not better solved otherwise. Perhaps the only saving grace is that in India's open social environment, such attempts do not have the human cost of the cultural revolution in China which started with similar demands for empathy and ended with a human tragedy. There was a satirical cartoon in the IISc students magazine which comes to mind. It depicted the design of an advanced bullock cart with all sorts of high technology additions; shock absorbers, low friction gears, solar panels etc. It may have been a bit unkind but depicts the reality of this desire for *appropriate technology*.

Paying lip sympathy to social justice, dreaming about a new science that will short circuit India's slow path of progress or a new scientific vision that will lead to an egalitarian heaven have not reduced the desire for accolades from the international scientific community either for the scientific fraternity or the society at large. Thus the Fellowship of the Royal Society (FRS) continues to be highly respected. While no Indian since Raman has actually got a Nobel prize in science (Physics Chemistry or Medicine), a few have been able to add FRS to their names. Still the numbers are

very small and hence there is a strong desire to create new awards so that more people can flaunt their own little baubles. If we do not get the others we will get our own!

Even here, the mental reservations against meritocracy are apparent. The first award of this type instituted in India is the Shanti Swarup Bhatnagar award. The very fact that this was named after Bhatnagar and not after scientists with more fundamental contributions to science and international reputation like Raman or Ramanujan is itself an indicator of things. At the prize distribution and announcement ceremonies I have heard the director general of CSIR stand with a straight face and compare them with the Nobel Prize! Really!! He does prove my point about the funny numbers quantifying science discussed in the earlier essay by digging out some numbers to support his comparison. The prizes are given by CSIR. Since the majority of these awards were not being claimed by the CSIR laboratories, some years ago, newer awards exclusively for the scientists at CSIR laboratories were introduced. Similarly INSA introduced the young scientist awards for encouraging youngsters. Very soon, similar awards were being given by CSIR and also by many state level science and technology departments. Proliferation of awards is quite natural but what of the quality of the work being recognized with these awards?

I have already argued, hopefully convincingly that the utility of science is defined by the extent to which the idea is useful to others. As I glance at the curriculum vitae of most Indians, one factor fairly jumps to the eye. In most cases and particularly in the case of the so called successful colleagues who had been recipients of many of these awards, there is a tendency to move from one material to another and one area to another. Rarely does an Indian scientist use his *novel* idea, published in one *prestigious journal* in more than one research publication. It is not merely the search for novelty! It is an admission that the ideas are so fragile that they do

not bear repeating. The eternal search for novelty or impact factor or citations or other numerical descriptors of work and rewarding them leads merely to making unsubstantiated claims. The sad reality of ideas selected for awards in India is the low confidence the awardees have for their own work. In such a situation to expect credit beyond the number game is quite useless.

Even more irritating than exaggerated claims of accomplishment and awards for mediocrity are claims of kinship and living in reflected glory. Thus the news media routinely highlights the accomplishments of people of Indian origin! This has two reasons. Firstly it supports that socialistic world view of most Indians where nurture is everything and the individual effort and competence are an after thought. The fact that Indians are able to *achieve in that system* obviates any necessity to hold oneself responsible for lack of real accomplishment. Often this is extended to comparisons between institutions. The superior performance of an individual from a *better institution* is explained as the consequence of better facilities. That there would be competition to get into those institutions is dismissed as an argument against social justice.

The Shanti Swarup Bhatnagar award is for work done in India. Several years ago there was a huge furore about the award being given to a person for work done abroad. Fair enough. But so many scientists move in and out of India. Would it not tarnish the image of the award within an institution when the best performers are not awardees. Of course this is a common problem with all efforts at social justice but it is less suitable in science. What is to be examined is whether such mixing of science awards and social justice has not become counter productive.

Realization of self inadequacy is also the reason why crazy claims about Indian science and civilization find a willing and

uncritical ear. This hero worship also results in anger if the scientific accomplishments of the great names of Indian science are honestly evaluated. A senior professor of physics was furious when I refused to endorse his silly claim that Einstein had stolen credit from S N Bose. Others were not happy that I had not eulogized Bose's contribution. My explanation that Bose's single paper emerged before the development of quantum mechanics by Schrödinger, Heisenberg and Dirac and that the division of quantum particles into Fermions and Bosons was much later work due to Pauli is usually resented as not being patriotic. Truth to tell, the reputation of Bhatnagar, Bhabha and other big names of Indian science owes more to their perceived role in nation building.

Even some of the ridiculous scientific claims made by distinguished Indian scientists is white washed. One still sees laudatory references to J C Bose's ideas that are clearly nonsense. At least in my earlier years in science, it was permissible to belittle only one scientist C V Raman. Both his mistake regarding Raman effect in diamond and his idiosyncratic studies on human vision in his later years were routinely ridiculed. The reason is not far to seek. His refusal to follow the post independent Indian socialistic philosophy. Refusal to make a realistic assessment of Indian science is almost universal. If the great are allowed their halos, the lack of critical outlook permeates every corner. Not that scientists must be or even can be emotionless automats. Desire for appreciation and other human limitations are bad enough limitations in individuals. When these become collective traits, it becomes disastrous for the community or the country.

Thus, the statement that India has third rate science and fourth rate technology makes sense. But can the doyen of Indian science escape his own complicity in the matter since no decision in Indian science was taken without his concurrence? Actually this tendency to make unrealistic comments is very common even

among the leaders of Indian science. A former director general of CSIR sent out an open letter on new year eve asking the scientists to among other things achieve unrealistic growth. It only gave me a hilarious time in the lab as a I explained to friends with example after example that nothing natural or man made can sustain that growth rate. As if to match this, a recent circular demanded a Strength, Weakness, Opportunities and Threats (SWOT) analysis in 24 hours. I suggested to my friends that a three word answer "Sir, you are nutts!" was most appropriate. It did not find favor. They preferred to imagine that the authorities knew the Charles Dickens quote, "Ask no questions, and you'll be told no lies." The lies recorded as the response were probably anticipated and satisfactory for those who asked the question.

Eight years ago when the then director organized a brain storming session at NPL, all my colleagues discussed the research being carried out in their groups and the plans for the next few years. Even though that was logical, I decided to perform a SWOT analysis of NPL. In some sense the present essays reflect the same philosophy I outlined in the brief time available for me during that presentation. I made the same demand as at present, that one has to make a realistic analysis. I pointed out that projecting from science to useful technology is impossible. Even Einstein and Rutherford failed to predict the viability of nuclear fission. Classifying research as academic and applied is not very sensible. The most useful algorithms for locating locations for drilling in oil industry were developed in the eighties for solving ground state of spin glasses. One has to thus concentrate on quality of science and critically examine claims of technology development.

The demands of courtesy have made open and critical examination of issues so far from daily experience that the major visible facets of Indian science are trying to make tall claims without any justification, consistent conspiracy of silence and refusal to be

critical of anything. This is balanced by a victim mentality best seen in the persistent propensity to hide information with expression of the fear that ideas would be stolen. This is in reality is either a mistaken assessment of their knowledge or a realization that all fools have; that it is best to keep quite! Consequently, real problems of Indian science have been completely brushed under the rug. Some are the consequence of our bureaucracy but some are the results of inefficiency of the scientists themselves. It is worth looking at these issues in the present narrative.

Raman with his acidic tongue made a sarcastic comment well before the current days of liberalized funding and importing of equipment. He shouted "Shah Jahan built Taj Mahal to burry his favorite queen. National laboratories are built to burry equipment". While this is extreme, surely one has to admit that it has a truthful ring to it. While we blame lack of resources, an audit of the utilization would horrify anyone. Unfortunately this is not an audit that be done anyone else. When an instrument, for example an electron microscope is purchased auditing its utilization is extremely difficult. How often had it been used to its highest magnification? How often is it used at all? How often has it been dysfunctional? I had offered odds to my colleagues that we could go into a room at random and find most equipment not even switched on!

We routinely accuse each other of incompetence and hoarding equipment. But, this inefficiency is unfortunately logical. In India, there is some chance of financial support for purchase of new equipment or setting up of new facilities. These are backed by alluring goals of advanced science and technology and are considered plan expenditure! But budget for maintenance is called non-plan expenditure and is routinely reduced whenever the government finances are stressed. This stupid approach which extends beyond science and technology is actually applauded in

the media as an evidence of the government accepting the challenge. The tendency to create new institutions rather than restore existing institutions is given a fillip by this stupidity.

More than twenty years ago in a fire, the central air conditioning plant at NPL had become inoperative. There was for some years a talk of replacing it. The then director asked a friend of his for advice and the gentleman, a general manager of a major manufacturer of air conditioning equipment came without intimating the director who was on tour. Since the security in the pre-terror era was quite lax he could just walk around, locate the plant and make a basic estimate. The consequent letter he wrote remained in my memory. He stated the obvious that many firms in India including his own could set up such a plant but mentioned that this would cost a few crores. Then came a statement that was an eye opener. He said, of course you realize that you will have to budget for about 10% as annual maintenance and a similar amount as depreciation to cover repairs and eventual replacement! For different reasons, mainly the constant alteration to the laboratory building, the proposal was never followed up. However, in the last few years as I watched a huge new building with state of the art facilities for cleanliness and temperature control come up in NPL campus, the memory of that sentence haunts me since we still rate maintenance lower than acquisition of new facilities.

Thanks to the media exposure of various scams, there is intense new desire to audit government expenditure. This has resulted in all pervasive restrictions on procurement procedures. I am constantly reminded of the response by the first American Astronaut John Glenn. When asked what his thoughts were as he was about to begin the journey into space, he quipped, I was thinking that everything in the rocket below me was supplied by the lowest bidder! Just like the defense procurement, the number of sources for supplies is very restricted and well known. Comparative

technical evaluation is more often a sham. Every such equipment has some superior and some inferior points. Applying rules for procuring cement or bricks to these transactions is silly. The only workable approach is to give complete freedom to the people involved. They should then be closely monitored to ensure that they have not financially benefited from the public expenditure. Unfortunately, there is little scope of such radical views being accepted.

In recent years, auditing of expenditure has been supplemented by the auditing of the scientific projects in their totality. Since this is done in the usual bureaucratic style, there are hilarious exchanges. One of our project proposals mentioned in passing that there could be possibility of technology transfer. Now this is admittedly an unrealistic goal. It would have been sensible for a technical evaluation of the project to have pointed out. But the listed objectives did not mention this and it was not given weightage. However the clerical team undertaking the audit jumped onto it and asked us to answer why the entire expenditure could not be treated as wasteful expenditure. I pointed out in my response that by this definition no scientific project can be justified. If the investigator could be so sure of achieving success, there was no research necessary and a bank or investor would be the better choice to approach for funds. So on the one hand while critical scientific examination is missing, there are attempts to replace this with more clerical oversight which is worse. It has also to be admitted that such audit only results in resentment and fudged numbers. Indian scientists are not immune to the national disease of fraternity. They try to backup each other so as to avoid disgrace to the community of scientists or their institution.

Just as they stress utility and disparage academic science, Indians tend to put a high value on team work and disparage individual efforts. But teamwork without efficiency is stupid. The

chain is as strong as the weakest link. If two scientists cannot identify that cooperation is mutually beneficial they are not competent to do good science in any case. If science managers expect that individuals can be persuaded to cooperate even when it is not in their personal interests they are naïve. In another context I simply pointed out to a senior scientist that if the efficiency of each scientist is 50%, the efficiency of a team of two scientists is 25% and that of a team of four scientists is 12.5%. He responded that he does not believe it. I shot back that reality exists despite our not believing it.

This is the fundamental reason why planning fails and leadership is irrelevant. Unless *each and every* individual steps constituting the whole plan are realizable with close to 100% efficiency, the plan is bound to fail. In a funny incident, many years ago a colleague claimed that the planned experiments could not be completed because of non-availability of liquid Helium. The director asked if given the availability of liquid helium in the previous years one was realistic in planning the target which required so much of a scarce commodity. Such critical examination of each step in the plan is necessary but sadly, such realism is sporadic and often selective. It is often employed to settle scores and out of vindictiveness. Consequently, critical evaluation of plans has also become a victim of courteous silence and is rarely a guide for future plans.

Instead of the aspiring for creative greatness, the Indian scientists exhibit what I prefer to call the Bhabha syndrome for reasons which will become clear very shortly. This is expressed in a desire to build facilities, laboratories or organizations depending on ones access to government money. As an aside, the only great man who resisted this was Raman, who built Raman Research Institute with his private funds and left his estate not to his wife but to the institute! The Bhabha syndrome has now extended to

the lowest levels. One routinely hears colleagues claim credit for the facilities big or small they have created while being felicitated at the time of retirement. One of my friends commented that Indian scientists always tell a visitor what facilities they have not what they have accomplished with those facilities.

The first major decisions after independence, towards the creation of scientific infrastructure have taken the form of DAE and CSIR. Including all the recent created institutions, at least ten of the sixty existing departments of government of India (central government as it is commonly called) are exclusively or primarily associated with scientific research. This is itself an astounding percentage. And every one of the other departments have some units, laboratories or institutions that deal with scientific research.

Every one of the major science departments be it DAE or the Department of Science and Technology (DST) has programs for funding research in other institutions, doing research in institutions under their supervision and administering academic institutions that have very little overlap with the department mandate. Thus the DAE controls no less than five academic institutions, the DST has more than a dozen and the CSIR has recently decided that every one of its laboratories will play a dual role and offer a masters degree in science or engineering.

There are mundane reasons for this approach like the desire to get retirement age and pay parity with academic institutions. They are sometimes efforts to bypass the bureaucracy of the University Grants Commission (UGC). Personal equations between senior scientists is often a cause. In the case of the CSIR the demands by university professors for credit and coauthorship as the payment for granting Ph. D degrees was a motivation. Primarily however, this multiplicity of institutions is another manifestation of the problem identified earlier namely creating new institutions

since one assumes that doing one can avoid the systemic problems which are the cause of others who failed. There is extreme resistance to admitting the primary faults.

The biggest attraction of the Bhabha syndrome aside from the government paying for it is that one can make these claims without any qualms. By the time your dream is a demonstrable failure, you are not there. In any case courtesy demands that you are not maligned. Leaders in India are lauded for their intentions and successes if any. No leader in India, not merely the scientists are ever asked to take responsibility for the failures.

The reason for the name Bhabha syndrome will now be obvious to anyone who read the earlier discussion of DAE. You can always lie or fool yourself. And as Feynman said the easiest person to fool is yourself. I strongly feel that courtesy in science led to courtesy as a cover to incompetence and no science.

Demands for demonstration of societal benefit are heard all over the world. Witness for example the comment I quoted regarding the particle accelerator at the start. It has to be conceded that these demands are a bit more shrill in India. Partly, this is a consequence of India being a poor country. But it is also an effective tool disparage the work of those whom one does not like for one reason or another.

I on the other hand subscribe totally to the line that Rudolf Mössbauer took as mentioned right at the start. As Feynman points out in his memoirs that the society does not need the latest science but implementation of known solutions. Science may offer better solutions but no one can translate the latest ideas into commercially viable products with certainty. The Bell laboratory, the IBM Thomas J Watson center and the Xerox Palo Alto lab survived as great centers of research on the profits made by the parent companies.

The companies did not survive from the royalties on the great ideas generated and patented there.

My conclusion in the SWOT analysis as it is in this narrative is that our ambitions are completely unrelated to our capabilities and that our plans are unrealistic, that we ignore opportunities to improve the performance in realistic ways since such goals do not appear attractive and that we end up *unwilling to do what we can and unable to do what we want*. My close friend took me to task that evening in private, saying I do not want you to tell me what I can, I want you to tell me how to do what I want! Sadly this is most people's idea of leadership.

Right at the start of my career I had an interaction with a senior professor which illustrates my consistent philosophy. I was a nursing a disappointment at that stage of my career about not being able to join a more prestigious institution than NPL and he tried to console me that a new director was going to take over and the future would be far better in NPL as well. I was not convinced and remember telling him that changing one man in an organization of sixteen hundred will make no impact.

At the national level I was never euphoric about the advent of Rajiv Gandhi thirty years ago nor of Narendra Modi now though many of my scientific friends were so inclined at one or the other occasion. Reliance on the leader to change things is in my opinion micro management. A senior scientist may have better understanding of the subject or the issues at hand but how much better? And how much time can he spend on the problem. He has so many to handle. Is it realistic to think that he can identify the solution in the few minutes he has while it has escaped the youngster in the hours and days he spends on the problem? It is only possible if it is one of those totally idiotic ideas which I highlighted through out this narrative.

Recognizing the disaster generated by demands of courtesy is more important than leadership. I would like to close with one example from my memory that illustrates this perfectly. At one point NPL had a high pressure extrusion pilot plant (HEPP). A committee was constituted to advice regarding its future. I was a youngster with no contact to either HEPP or the committee but one of the members was a friendly senior figure from my Ph. D days. He frankly admitted in private that the best that could be done was to ask a businessman to run it as a work shop and it could make some money for NPL. But he simply agreed to whatever the scientists concerned wished to do as usual, because *courtesy demanded it*.

"Success is not final, failure is not fatal: it is the courage to continue that counts." This is a favorite quote of mine from Winston Churchill. But it is most important to recognize reality. And Feynman puts is best. After his damning indictment of NASA for the challenger disaster he says "For success in science and technology, reality has to take precedence over public relations for nature cannot be fooled".

Unfortunately, the problems of Indian science closely mirror the malaise I identified earlier with India in general*, whining about the importance of the system, social justice, team work and leadership all of which mask an unwillingness to accept reality which in turn is a consequence of incompetence leading to indiscipline.

I once took a senior friend of mine outside NPL main building, pointed to the spring flowers in their pots and the blooming gulmohar trees in the distance and revealed my choice. "*Genda nahi gulmohar chahiye*". I want *Gulmohar* (Royal Poinciana or flame of the forest tree) which is independent once planted and delivers glorious blooms year after year without a

gardener, not seasonal marigolds that have to be planted and nurtured every year. Going back to that interaction with Mossbauer, referred to earlier, a decision whether to have science or not is for the society. As the professor from the science academy of USA claimed science could make a country worth defending! But only if it is work at the best level!

* India: MY India, Print on demand publication. pothi.com/pothi/book/s-t-lakshmikumar-india-my-india

V
A goddamn philosopher

The title of this eulogy for Richard Feynman is taken from a published letter of Freeman Dyson. It quotes Feynman complaining about his son wanting to become "*a goddamn philosopher*". Feynman had deep disdain for philosophy and for that matter many other social sciences. But his writings have helped me, a justifiably unknown scientist to understand the world better. This is what the average person calls philosophy. Feynman is perhaps the most popular author from the grave. So much *non-scientific writing* has been culled from his personal papers and published after his death that in my opinion he would probably have grumbled too that the world has made him *a goddamn philosopher*.

In this essay, I only refer to those of his experiences that had an impact on my own understanding of the world. The experiences he shared and comments he made enabled my own meager efforts in the last ten years to write on a variety of subjects in a medium quite distinct from my earlier experience of publishing

research articles in professional journals. His writings were the basis of my realization that philosophical enquiry most properly is the ability to understand the limits of further scientific analysis. So these examples have a personal importance to me. These are taken from the published books but have been grouped subjectively, mostly without quoting exact words or referring to specific books.

Most people have an awe about philosophy and philosophers. I was no different. In just a few sentences describing his undergraduate experience, Feynman banished this for ever. He attended a course on philosophy discussing the work of the famous philosopher Whitehead. As part of this, something called an *essential object* was defined. This was early years of quantum physics and so philosophers were keen to fit new scientific facts into their theories. When asked if an electron was an essential object as defined philosophically, he countered by asking if a brick was an essential object. The responses he quotes were hilarious. More importantly this graduate student correctly noticed that while precise definitions can be given by philosophers they rarely have any applicability in real world situations.

Precision in language ignores the fundamental fact that words themselves, apart from everyday objects have no precise meaning. They are merely defined in terms of other words. Thus when interacting with philosophers and their first cousins, theologians, one gets merely jargon and not understanding. A lot of what I read earlier suddenly started to unravel and reveal itself to be a pantomime of Anderson's fairly tale *The emperor's new clothes*.

The way he took on Descartes the great philosopher while being a high school student visiting his girl friend was equally entertaining. According to the school text book, Descartes in effect said that when we know that something imperfect, for example a

human being exists, we can infer the existence of something perfect or God. Something imperfect cannot otherwise be known. Feynman simply pointed out that one can have an approximate understanding and an approximate scientific theory even if the absolutely perfect theory is not known. So this claim of Descartes is not valid.

When something is generalized it resembles philosophy. Philosophy changing drastically when it incorporates new theories of physics. But the theories may be relevant only in very selected areas of physics. For example, relativistic corrections in the context of physics are significant only in the quantum limit and at extremely high speeds. They are not needed at all in most of classical physics.

In philosophy, there would be drastic differences between theories which use the relativistic ideas and those which do not. There will be no easy way to support one over the other. Similarly, quantum theory shows that our intuition of what nature is going to do fail miserably. A description of quantum processes in ordinary language is impossible. Thus, using this latest scientific theory as a basis for philosophizing is most often hilarious if one questions it seriously.

He retained this no nonsense approach to challenge scholars in other subjects. He attended a discussion meeting on the ethics of equality which included experts from various disciplines; philosophy, sociology, religion etc. The others agreed to a consensus document as the summary of their discussions. Feynman had no qualms in proclaiming that it did not make any sense. That each sentence while appearing to make sense in fact made none. His ridiculing of people outside the science disciplines was legendary. In later years, this resulted in some of the scholars in these areas walking out of his lectures. But as far as I could search on the internet, they never countered his criticism of these human endeavors in a language that a lay person could grasp.

I was among those who was puzzled by the books like *The Tao of Physics* and *The Dancing Wu Li Masters* which sought to link religious mysticism and quantum physics. Feynamn's QED was my guide to unraveling the confusion. I was amused to realize how easy it was to be bamboozled by verbosity and experienced first hand what he meant when he said that the easiest person to fool is yourself. This descriptive account of quantum physics, meant for lay audience has been very useful to the development of my own understanding of quantum physics at the deepest level.

It also led me to an amusing interaction which proved that even the best can fool themselves. Today, experiments which were only imaginary *thought experiments* in discussions between Einstein and Bohr, when quantum theory was being developed can be actually performed. I found a popular article by a French scientist who was performing cutting edge work in this area. In it, he was once again discussing the mysterious *collapse of the wave function*, one of the major issues for the books mentioned above. Of course, he was not making religious, mystic analogies. I wrote to him asking if he did not think this mystery would be lost in the path integral formalism of Feynman. In his reply he said that he considers the path integrals to be merely mathematical! But the wave function formalism is mathematically equivalent to the path integral formalism. So even the so called collapse of the wave function is properly a mathematical construct needed to explain experiments. The response of the great scientist is, as Feynman would have put it only a cop out, trying to escape from a tricky situation. Obviously, even the most accomplished can fall into this trap of fooling oneself. Capability does not seem to matter when one is actually looking for mysteries.

The fact that Feynman could as a graduate student understand the limited utility of analogies in areas like language and philosophy impressed me. He explicitly said so to a visiting

professor. He helped me distinguish this weak analogy from the essence of mathematical theories. These insights into the nature of physics were a key influence on my effort to understand the strength of various scientific disciplines. Thus, I developed the audacity to enquire if all scientific claims in physical sciences were equally strong and then extended this to understand the limitations of environmentalism and economic theories.

Feynman's contribution to the investigation of the disaster of the challenger space shuttle has been extensively covered by the media. Most people appreciate his simple experiment to identify the cause of the failure. By dunking a piece of rubber ring used in the shuttle in ice water he showed that it would become hard and fail. This was something the designers should have realized but did not. There are the odd accusations of playing to the gallery and hogging the limelight about this demonstration. But for me, the key input was that a critical and honest assessment actually delivers better than the analysis of experts. After all, Feynman had not designed any part of the spacecraft or even a subsystem, but could identify the real problem.

The analysis he provided as an annexure to the report of the commission is a good case study for everyone interested in the pitfalls in team efforts. He demonstrates that unsubstantiated claims become official dogma when they are not immediately challenged. Having made these claims for some time, the seniors would become very resistant to admitting their mistakes. He explained how easily communications up and down a hierarchy had possibly become non existent inside NASA leading to the disaster. Once the seniors become unwilling to listen to bad news or problems at the lower level, the juniors simply stop intimating them. He demonstrates how unrealistic targets are projected in a bid to attract political and thus financial support. All these inputs have been most useful for my own analysis of Indian science made in earlier essays.

The most impressive thing about Feynman is his intense commitment to science. He honestly admitted that a place like Caltech was exactly right for him since his own interest did not go beyond science and technology. When it came to science he had no qualms about calling a spade a spade. Discussing NASA he bluntly noted that while NASA claims to learn from failures like the challenger disaster, the only thing learnt was not to be stupid! The causes of such disasters are very simple errors that should have been recognized.

He firmly noted that while the general public is mesmerized by space exploration as an important component of science, this is not borne out by actual publications in professional scientific journals. In the same vein he pokes fun at theoretical physicists including himself. The area in which he worked, studying the interactions between particles like photons, electrons and quarks is called *fundamental physics*. He joked, "we stole that name to give other physicists an inferiority complex". He elaborates that to study the world around us, solids, liquids etc., is actually honest physics. I am constantly reminded of this caution in recent years when the world around me is growing crazy about the Higgs Boson.

In a letter to his family he lambastes science being done in Poland and in another describes how ancient worship can really harm. He humorously describes the Greek tendency to incessantly belittle themselves and glorify the ancient Greeks. As he correctly pointed out, there has been enormous progress in science and mathematics since ancient Greece. They can only be praised in a historical context. This lesson would be as valuable for all Indians as it was to me. He was furious with the Greek archeologists who could not appreciate the enigma of an intricate machine that was discovered. It remains an enigma to this day. No simpler machines leading up to it have ever been discovered. Everyone makes such comments and generalizations on topics close to ones heart in

private communication. It is easy to say that Feynman could afford to be vocal in public. What is more important has been his ability to convince the others of his sincerity. He made scathing remarks about teaching of physics in Brazil, pointing out that most people seem to learn by rote without understanding. The hosts conceded that while this criticism hurts, they had to take action rather than get upset since Feynman was sincere in his love for science. That incident was once again a pointer to me that at every level, including my own, honest criticism will be accepted if one is really sincere.

The criticism I made of the courtesy demands in Indian science were triggered by the description I read about his lecture on the theory of superconductivity. He had not succeeded. But he described in loving detail all the various trials he made without success. It had a really positive impact on the people who actually succeeded in developing that theory. Albert Einstein commented in a similar context that publishing or making public your mistakes prevents another person from making the same mistake. For those not in that league, it reveals a standard of integrity necessary for science.

As in many disciplines, the brotherhood of scientists tries to cover up each other's mistakes. In the earlier essays, I have been critically examining Indian science. Such instances are known elsewhere. It is once again only Feynman who opened my eyes towards these problems. He described the results of experiments performed following the initial determination of the mass to charge ratio of an electron by Millikan. We now know that Millikan's result had an experimental error. But the successors published their results only when they were close to the first erroneous value. The accepted value slowly and gradually corrected itself. It is clear that either people who got results much further from the first value could not get their results published in which case the reviewers were mesmerized by greatness of the initial results or the they did not

even try to publish such results assuming that they were wrong, which means that the experimenter was the one mesmerized.

His lecture on cargo cult science is extremely famous. It is a great lesson to those who learn science by memorizing and these days by googling for information. It is not very surprising that he could teach a little child to appreciate the concept of infinity. He taught me that admission of ignorance is important. But this admission is not a commandment to simply accept the expert. He objected to the medical doctors who were treating his first wife for forcing everyone to use precautions while there was no actual blood test to confirm their diagnosis. That was another instance when he would challenge experts outside his own specialization. It was an era before antibiotics and most modern medicine but it is not uncommon even today to find medical experts who do not bother to ensure that the comments they make are in accordance with modern medical consensus and practice.

As if to balance the foolishness of those who are recognized as experts he brings in his interaction with a house painter. The painter makes tall claims about how to mix colors and when Feynman finds the claims absurd he brings the paint cans and forces the painter to admit that he was talking through the hat. He makes an effort to get to know a professional gambler in a casino. Feynman correctly calculates that since the odds in a casino are never in favor of the gambler, no one can live as a professional gambler. He finds that there is lot of gambling that goes on in a casino beside the official version and concludes that the professional gambler, Nick the Geek is a clever guy. He then concludes by saying, *I have to understand the world*. That dictum has been of most use to me.

One of my interests has always been to understand the various political and social organizations of humanity. I found his conclusion that democracy is simple trial and error and close to

the experimental method of science most illuminating. Perhaps others have said it before. The patron saints of American democracy, Thomas Jefferson and Benjamin Franklin were accomplished scientists. But he was more useful than any of the philosophers and statesmen I read. He simplified the problem by showing that ideologies are in the scientific language extrapolation from a limited number of observations. These will have limitations since the extrapolation does not take into consideration either the strength of the data or of the process of extrapolation.

People who decry fundamentalist ideologies are very common. In some sense each ideologue accuses those opposed as a fundamentalist. My eyes certainly were opened by his description of those who hold on to the original version of the American constitution as constitution fundamentalists. After all, as he sagely pointed out, there is a specific provision to modify the constitution! The original version has no sanctity to those who wrote it! Those who attach such sanctity to the document are exposing their tendency to hero worship. That insight was very crucial for my own understanding of both India and science.

The most important things in life are actually non scientific. It was pointed out by a great scientist Poincare that a philosopher from classical Greece may be all at sea discussing physics or mechanics with us but would be perfectly comfortable arguing the finer aspects of philosophy or aesthetics. Feynman with his impish humor makes himself the but of a joke to illustrate this. His wife makes him admit that he can appreciate the beauty of Chinese calligraphy without being able to define beauty.

Religion is another of these issues that cannot be logically analyzed. Logic simply leads one to a hard atheist position, that all religions are based on fairy tales and ancestor worship. Surprisingly, Feynman takes a slightly nuanced position. He admits that while it

is difficult to believe both religion and science, it is possible. On the one hand he was clearly an atheist himself and not one to govern his conduct according to any organized religion. He said "…if you understand reality and take it completely into your heart, are irrelevant and unsolvable. They are just things that nobody can know. Your situation is just an accident of life". It did occur to me that most people, atheists included do not pass that test and so may possibly benefit from religion. On the other hand, he passed on the comment of a Buddhist monk "To every man is given the key to the gates of heaven. The same key opens the gates of hell" with a nod of approval.

His views encouraged my exploration of the boundary between science and religion with an open mind. He helped me to understand why the Gandhian moral instruction "Recall the face of the poorest and weakest man you have seen, and ask yourself if this step you contemplate is going to be any use to him." is emotionally very satisfying but practically unworkable. (How long should I introspect and what if it helps him but harms a few others marginally better than the example.)

On the other hand Feynman's approach made me understand many problems faced by contemporary believers. The faithful have a believe in the efficacy of prayer or that saints can work miracles. Scientific examination on the other hand fails to confirm these. This boundary between recognizing and using the methods of science and acting according to religious practice is very challenging. My own exploration of this area* owes a lot to Feynman's comments.

Many other issues he personally examined and recounted in his memoirs had influenced my outlook as I tried successively to understand for myself the nature of religion, the problems of India, ignorance and uncertainty in science. Some of the most

illuminating were his early efforts to understand how the stream of consciousness ends as you go to sleep. He experimented with a friend about simultaneously tracking time and counting and came up with a profound insight. Even such simple everyday task as counting may involve different psychological processes for different people. That thinking is mostly verbal is a commonly expressed idea. He simply stops it by quoting a school friend who had asked him to imagine the shape of a crank shaft.

He experimented with sense deprivation tanks where the there is no sound, light, sense of touch or even gravity. This is accomplished by floating in a high density fluid inside a closed box. He described the failed efforts to understand conscious states. He however declined to experiment with even recreational drugs. He had also stopped drinking alcohol in midlife. These were strong influences on my own positions regarding issues like legalizing recreational drugs or on prohibition. Quite apart from that, these helped me to critically examine various discourses regarding yoga as I tried to fathom my own Hind faith.

He also taught me that questions like "Does political correctness destroy moral fiber when you lie for it?" for which one does not have answers are still worth exploring. His interaction with a black taxi driver in the Caribbean island was quite an eye opener. The taxi driver pointed out to Feynman that Asian Indians who were equally poor were forging ahead of blacks in his country and asked why. Feynman gave an answer that was politically incorrect. He called it an advantage accrued from Indian culture. He however used very soft language and made it very clear that he was advancing it as a hypothesis and was not dogmatic about it. That ties in nicely with his views regarding democracy and helps one to come out with a proposal for reforming the society one lives in without demanding its implementation without societal approval.

This quote from him has been a cornerstone of my efforts outside my career as a professional scientist. "It is our responsibility as scientists, knowing the great progress which comes from a satisfactory philosophy of ignorance, the great progress which is the fruit of freedom of thought, to proclaim the value of this freedom; to teach how doubt is not to be feared but welcomed and discussed; and to demand this freedom as our duty to all coming generations". The benefit I got from this little nugget of wisdom alone justifies adding this little memoir to this little book.

---

* On Walking The knife Edge Of Science And Religion Print on demand publication. pothi.com/pothi/book/s-t-lakshmikumar-walking-knife-edge

This book is mostly a narration of my experience in science starting with my school days and through the many years in scientific research. I have used these as the basis for a very critical evaluation of science as it is being perused in India. I have made a personal analysis of Indian science, knowing fully well that anecdotes are worse than even statistical correlation as the basis to identify causes. As the title makes clear, I can not justify my analysis with an aura of professional accomplishment. Neither is the analysis an excuse or justification for my failure. The analysis may appear unnecessarily harsh and very pessimistic but I hope that readers and critics would still concede that the motivation was only the sincere conviction that this bitter medicine is needed for the betterment of Indian science.

About the Author: Dr S T Lakshmikumar obtained his doctorate in physics from Indian Institute of Science, Bangalore and worked as a scientist at the National Physical Laboratory, New Delhi. His earlier works for general audience are “The quest for new materials” (2005) and “Experimenting with the quantum world” (2009) published by Vigyan Prasar and “How well do we know it?”, “On walking the knife edge of science and religion” and “India: MY India” through Pothi.